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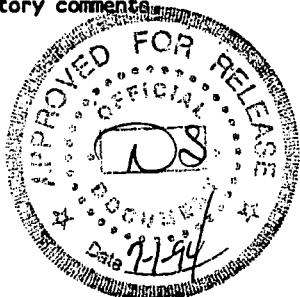
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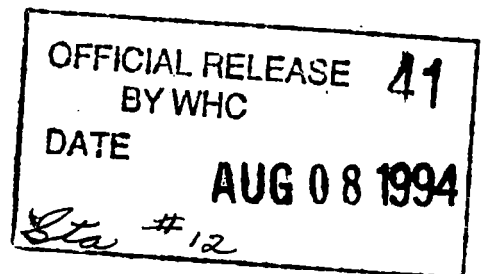
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EXECUTIVE SUMMARY

Alternative Remedial Technologies, Inc. (ART) of Tampa, Florida, was selected in a competitive selection process to conduct a pilot study for the physical separation of soils in the North Process Pond of the 300 Area at the Hanford Site. The North Process Pond pilot plant study is part of the 300-FF-1 Area CERCLA response. Westinghouse Hanford Company (WHC) was the manager of contract MJK-SVV-322846.

A significant level of effort had already been performed at the work site to characterize the soil, and a preliminary soil washing study using physical separation technology had been performed by WHC using components of the U.S. Environmental Protection Agency's "Volume Reduction Unit" (DOE-RL 1994a). The results of the previous work were used as the basis of ART's study. During the first quarter 1994, the ART team underwent the required site training and prepared a detailed test procedure that was reviewed and approved by WHC. This document, *Soil Washing Physical Separations Test Procedure* (ART 1994b), became the guiding document for the study.

In January 1994, ART mobilized its 15 tons-per-hour pilot plant to the site. The plant was initially staged in a commercial area to allow for pretest inspections and minor modifications. The plant was specifically designed for use as a physical separations unit and consisted of a feed hopper, wet screens, hydrocyclones, as well as settling and dewatering equipment. The plant was supported in the field with prescreening equipment, mobile generators, air compressors, and water storage tanks. The plant was moved into the surface contamination area on March 24, 1994.

The testing was conducted during the period March 23, 1994 through April 13, 1994. Two soil types were treated during the testing: a natural soil contaminated with low levels of uranium, cesium, cobalt, and heavy metals, and a natural soil contaminated with a uranium carbonate material that was visually recognizable by the presence of a green sludge material in the soil matrix. The "green" material contained significantly higher levels of the same contaminants. Both source materials were treated by the plant in a manner that fed the material, produced clean gravel and sand fractions, and concentrated the contaminants in a sludge cake. Process water was recycled during the operations. The testing was extremely successful in that for both source waste streams, it was demonstrated that volume reductions of greater than 90% could be achieved while also meeting the test performance criteria. The volume reduction for the natural soils averaged a 93.8%, while the "green" soils showed a 91.4% volume reduction.

Based upon the success of the study, soil washing using physical separation techniques has been shown to effectively meet the test performance criteria. Therefore, soil washing has been included in the Phase III Feasibility Study for the 300-FF-1 Operable Unit as an applicable remedial alternative for further evaluation.

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1.0 INTRODUCTION

This report describes the approach and results of physical separation pilot tests performed by Alternative Remedial Technologies, Inc. (ART) of Tampa, Florida. The pilot study was performed under the Westinghouse Hanford Company (WHC) Purchase Order No. MJK-SVV-322846. The work performed is a portion of the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) response at the Hanford Site and is focused on the North Process Pond of the 300-FF-1 Operable Unit.

Physical separation of soil is the most basic of a series of technologies commonly referred to as "soil washing." Physical separation was identified in the Phase I and II feasibility study reports for the 300-FF-1 Operable Unit as an alternative for remediation at the site. Tests were conducted earlier by WHC using a system developed at Hanford. The system that was used consisted of modified U.S. Environmental Protection Agency (EPA) equipment integrated with screens, hoppers, conveyors, tanks, and pumps from the Hanford Site. The EPA equipment was transferred to the U.S. Department of Energy (DOE) by the EPA Risk Reduction Engineering Laboratory, Edison, New Jersey. The results of the WHC work were reported in the *300-FF-1 Operable Unit Remedial Investigation Phase II Report: Physical Separation of Soils Treatability Study*, DOE/RL-93-96 (DOE-RL 1994a).

The scope of this report is limited to the work conducted in the North Process Pond during the period March 15, 1994 to June 1, 1994. The primary contractor was ART, supported with the Allied Technology Group (ATG) as a subcontractor. Onsite laboratory analysis was performed by ART with support from Pacific Northwest Laboratory (PNL). Offsite analytical support was provided by the Roy F. Weston Laboratory, Lionville, Pennsylvania, and analysis of quality assurance split samples was provided by Data Chem Laboratories, Salt Lake City, Utah.

The pilot study described in this report consisted of four parts, which processed a total of 348.2 tons: (1) a pretest run to initially configure the pilot plant and adjust system parameters for soils to be processed; (2) a verification run to define the performance of the system; (3) a replication run to confirm the findings of the verification run; and (4) a uranium carbonate run ("green material") in which a uranium carbonate material containing significantly higher levels of uranium was treated.

The purpose of the ART pilot testing was to determine if physical separation techniques could effect a significant volume reduction of the North Pond materials while using a small production plant to meet the test performance criteria and to obtain additional scale-up and cost information for a full-scale system.

1.1 DESCRIPTION OF THE SITE

The 300-FF-1 Operable Unit is located north of the city of Richland, Washington, and borders on the Columbia River. It covers an area of 0.57 km² and consists of approximately 0.14 km² of liquid disposal sites. The North and South Process Ponds and trenches were used between 1943 and 1975 to receive process wastewaters. The North Pond was constructed in 1948 when a dike in the South Pond failed. As with the South Pond, the North Pond had no outlet, and water was allowed to evaporate or infiltrate into the soils underlying the pond. The

ponds were dredged periodically to improve infiltration. The dredged soils were spread on the dikes or buried in the North Pond scrapings disposal area. Portions of the North Pond were also used to dispose of fly ash from the 300 Area ash pits. The ponds were deactivated in 1975 and currently do not contain any liquids (DOE-RL 1994a).

The process trenches were constructed in 1975 to replace the process ponds. In 1991, sediments were removed from the trenches and were stockpiled at the north end of the trenches. This action was part of an expedited response action in an effort to prevent the mobilization of soil adsorbed contaminants into the groundwater (DOE-RL 1994a).

1.2 SOIL/CONTAMINANT CHARACTERIZATION

The soil surface at the Hanford Site is characterized by a layer of light brown natural and wind-deposited sand and natural occurring gravel in the range of 5 mm to 150 mm (6 in.). The distribution of these soils prior to the conduct of the ART study was determined by WHC and PNL, and the findings documented by DOE-RL (1993) and Serne et al. (1992) were used as a baseline.

Underlying the surface soils are poorly sorted, unconsolidated glacial tills informally referred to as the Pasco gravels of the Hanford formation. The Pasco gravels consist of a variable mixture of boulders, cobbles, gravel, sand, and silt (DOE-RL 1994b). Most of the material, however, can be classified as a silty, sandy gravel consisting of 50% gravel, 40% sand, and 10% silt. The thickness of the Hanford formation in the 300 Area varies from about 9 to 20 m (DOE-RL 1994b).

Beneath the Hanford formation is the Ringold Formation, which consists of horizontally stratified deposits of sand, silt, clay, and gravel. This formation overlies the Saddle Mountain basalt formation and in the 300 Area varies in thickness up to 44 m (DOE-RL 1994b). The uppermost aquifer at Hanford is an unconfined system within the Hanford and Ringold formations. Across Hanford, the top of the unconfined aquifer ranges from less than 0.3 m to over 91 m in depth (DOE-RL 1993). In most places at Hanford the aquifer is in the Ringold Formation, which is too deep to reach by excavation methods. Therefore, it is expected that only the surface deposits and Hanford formation soils are of interest to physical separation methods.

The North Pond is the specific area of interest for the conduct of this physical separation study. The North Pond was constructed in 1948 to receive process sewer wastes. The wastes included process water from nuclear fuel fabrication operations, cooling water, steam condensate, water treatment salts, and a wide variety of waste liquids from laboratory drains in the 300 Area. The North Pond was deactivated in 1975 and currently does not contain any liquids (DOE-RL 1994b). Schematic drawings of the 300 Area and the North Pond are shown in Figures 1-1, 1-2, and 1-3.

Radioactivity levels in soils near the inlet end and west side of the North Process Pond ranged from 15,000 to 35,000 disintegrations per minute (dpm/100 cm²) as measured in the field in tests conducted during June 1993. Typically, the surface radioactivity levels of soils in the remaining portions of the North Pond were measured at approximately background levels, or approximately 500 dpm (DOE-RL 1994a).

The highest levels of radioactivity in the North Process Pond are found in a sludge-like, "green" material containing uranium-238. Further evaluations of the "green" material indicated that it consists of a uranium-copper carbonate. The green material was originally deposited in thin layers at a depth of 1 m to 1.5 m below the pond surface on the west side (DOE-RL 1994a). However, during the study, green material was also noted in disturbed areas in other parts of the North Process Pond.

1.3 TECHNOLOGY OVERVIEW

As noted in Section 1.1, physical separation is one member of a broad group of technologies referred to as soil washing. In its simplest application, physical separation technology refers to water-based processing of excavated soils by size fractionation such that a large portion of the processed feed soils meet the treatment standards, while soil contaminants are concentrated in a small soil mass. Therefore, the soil is "washed" by removing the selected sizes of particles that contain the majority of the contaminants from the bulk soil. Enhancements to physical separation technology can include grinding of the soil particles (referred to as attritioning) to remove surficially bound contaminants from the soil fractions or floatation techniques to separate various components of the finer soil fractions.

The physical separation technology does not use chemical extractants or surfactants to solubilize or dissolve the contaminants. The use of chemical solvents such as acetone or methanol; strong acidic or basic solutions including organic acids, mineral acids, or hydroxides; and strong surfactants with or without chelating agents such as ethylene diamine tetra-acetic acid (EDTA) constitute other groups of technologies within the context of "soil washing." These technologies may be used individually, or in combination with physical separation techniques to remediate contaminated soils. However, these chemical-intensive technologies require additional engineering and process controls to address safety concerns as well as minimize the residual extractants remaining in the process products. For ease of application, physical separation is preferred if the technology can meet the remediation goals selected for a particular site.

The ART physical separation operation used at the North Process Pond consisted of a rough screening unit, a feed hopper, a double-decked wet screen, a hydrocyclone separation system, sand dewatering screen, fines consolidation, thickening, and dewatering, as well as the required supporting facilities. For treatment of the soils containing the "green" material, the system was supplemented with an attritioning unit. The plant is described in detail in Chapter 3.0.

Figure 1-1. The Hanford Site (DOE-RL 1994a).

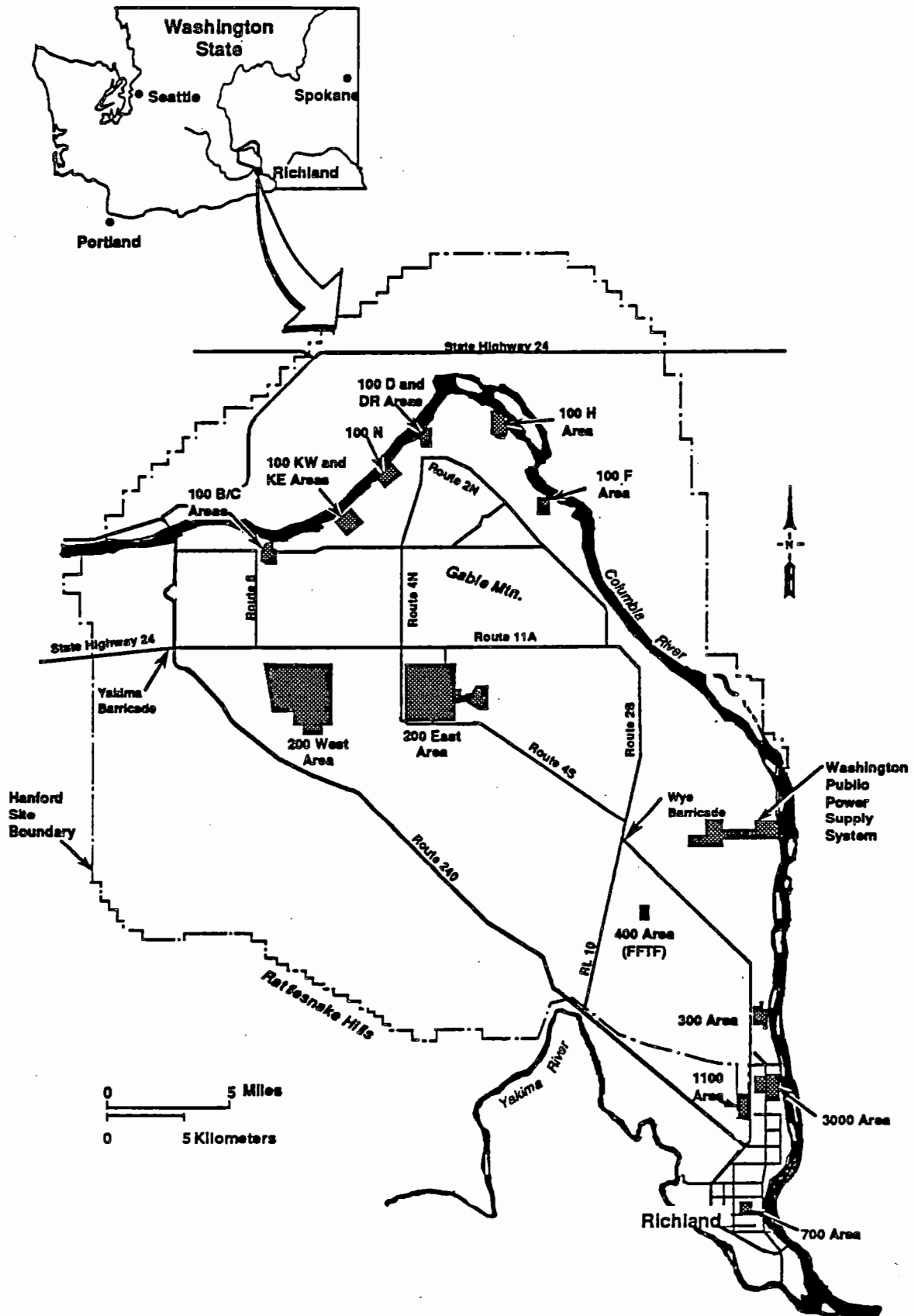


Figure 1-2. The 300-FF-1 Operable Unit, North Process Pond (DOE-RL 1994a).

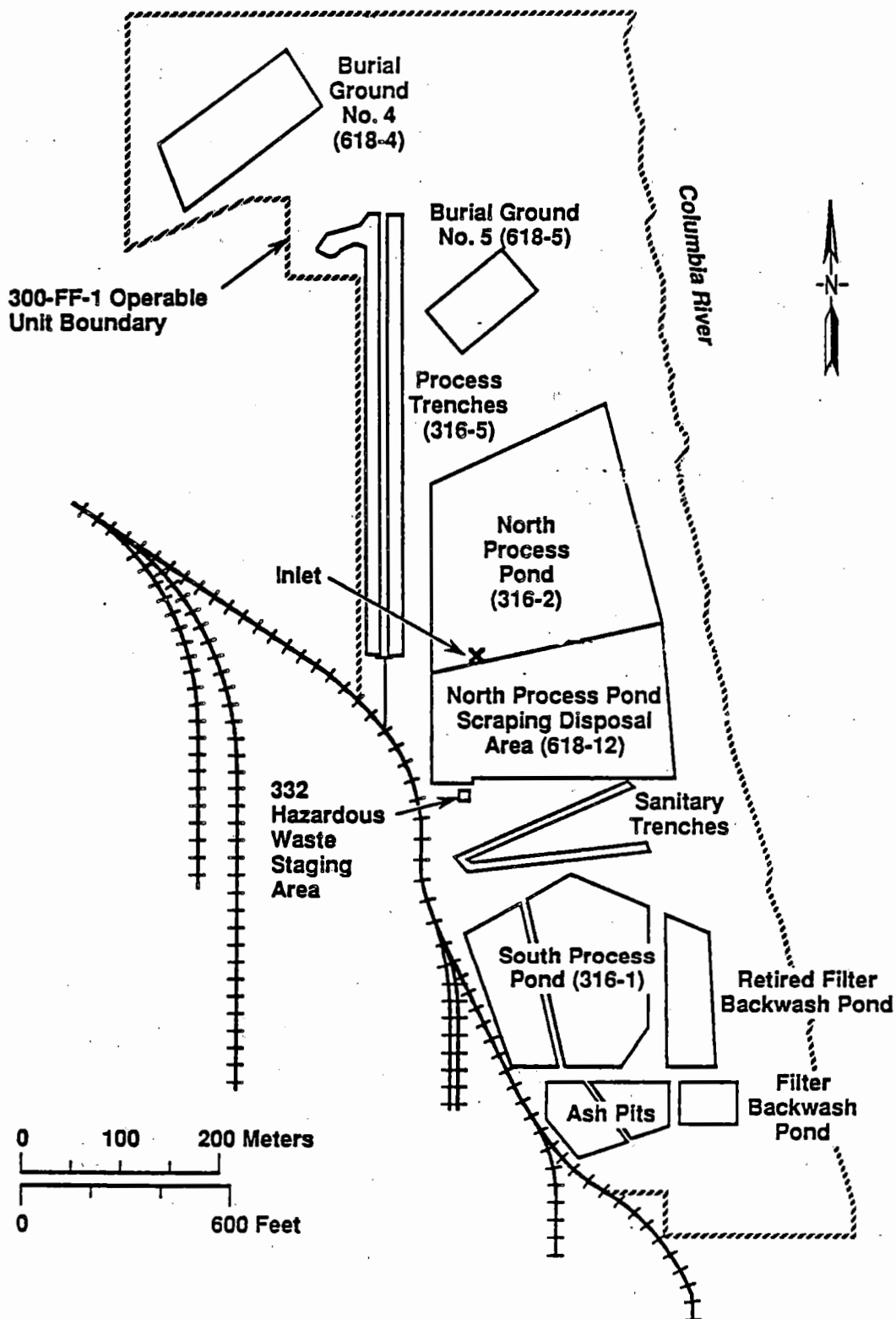
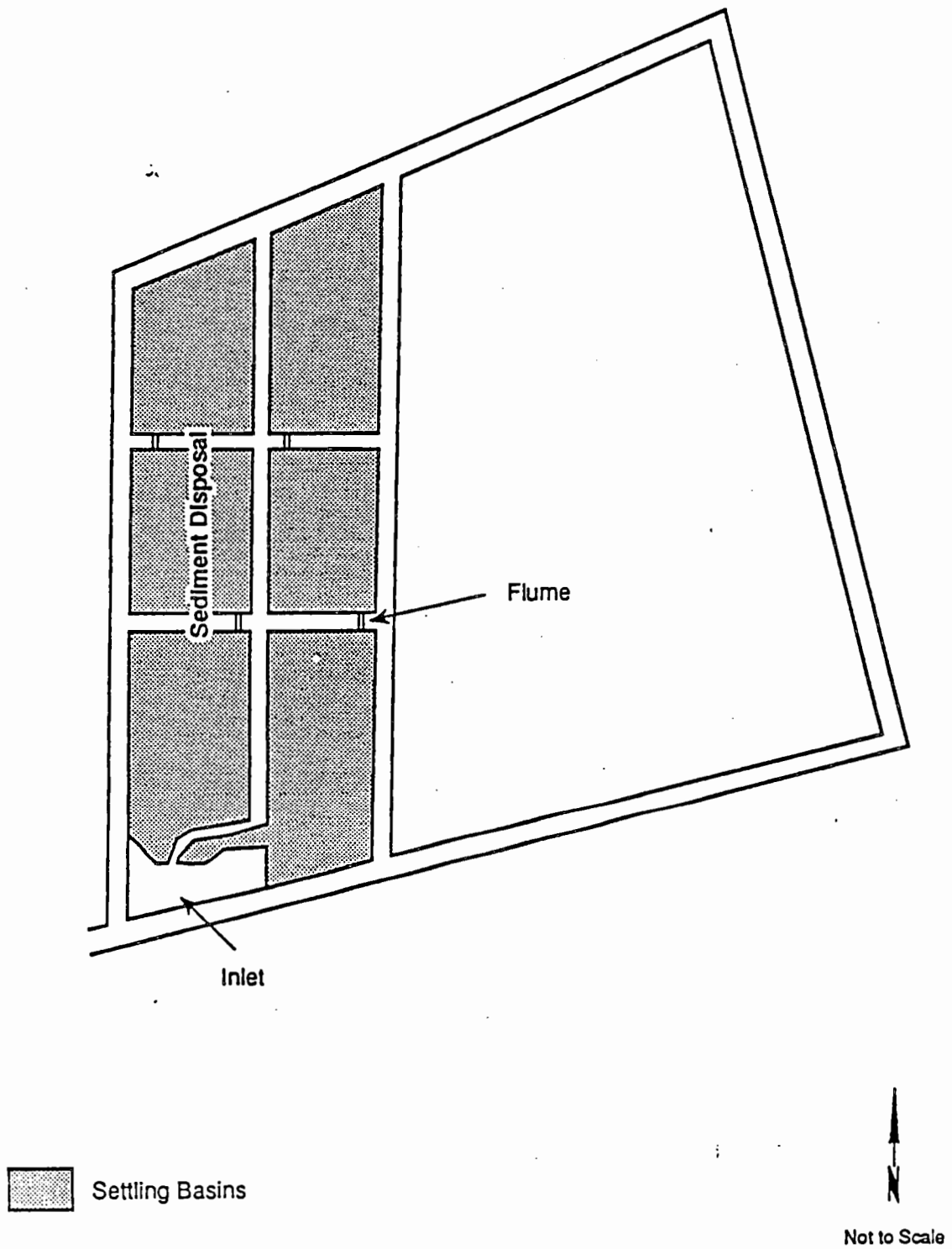


Figure 1-3. Operational Configuration of the North Process Pond (DOE-RL 1990).



2.0 DESCRIPTION OF THE TREATABILITY STUDY

2.1 TEST OBJECTIVE AND RATIONALE

The objectives of the study were for ART to provide services and equipment to WHC to demonstrate the ability to use a water-only physical separation soil washing process to treat contaminated soils in the North Pond of the 300-FF-1 Operable Unit at the Hanford Site. The process was intended to separate heavy metals and radioactive elements from contaminated soil fractions in order to meet specified test performance criteria. The test performance criteria are shown in Table 2-1.

Certain basic technical requirements were specified in the contract, and include the following.

- Chemicals could not be used in the process, except for nontoxic chemicals to enhance settling/flocculation of particles or for water treatment.
- The clean fraction of soil is expected to be greater than 90% by weight. The contaminated soil fraction resulting from the process should be 10% or less of the total soil processed on a weight basis. The 10% fraction must include any secondary radioactive waste.
- The equipment provided must be mobile and have a throughput capacity of 10 to 20 tons/h for the test.

This study is conducted as part of the CERCLA remedial investigation/feasibility study process for the 300-FF-1 Operable Unit. The results of the study are addressed in the Phase III feasibility study report (DOE-RL 1994b), which includes an evaluation of the applicable remedial alternatives.

2.2 EQUIPMENT AND MATERIALS USED

Equipment and materials used are shown in Table 2-2.

2.3 OPERATING ELEMENTS EVALUATED

The operating elements that were evaluated in the test were as follows:

- The use of prescreening techniques to remove the gross oversize, prepare an acceptable plant feed material, and control fugitive dust emissions
- Soil handling requirements
- Wet screening operations and separation efficiency related to the production of a clean process oversize

- Hydrocyclone configuration and optimization of the sand/fines separation point ("cut point") and hydrocyclone separation efficiencies
- Polymer selection and use for the settling, consolidation, and dewatering of the fines into a sludge cake
- Supporting system adequacy including water storage, product storage, and power generation
- The field sample preparation and the use of onsite X-ray fluorescence (XRF) analyses.

2.4 SAMPLING AND ANALYTICAL PLAN

A detailed sampling and analytical plan prepared, approved, and utilized for the study was entitled *Soil Washing Physical Separations Test Procedure* (ART 1994b). The primary sampling and analysis objectives of the project were as follows:

- Determine the physical characteristics of the soil and treatment products
- Determine the distribution and concentration of contaminants in the soils before and after physical separations are conducted
- Evaluate the separation efficiencies relative to soil types and contaminants
- Obtain samples and analytical results of sufficient quality to document the performance of the system in meeting the volume reduction objective and the test performance standards.

Table 2-1. Test Performance Criteria.

Analyte	Units	Concentration
Metals	ppm	
Antimony		128
Arsenic		320
Barium		22,400
Beryllium		172
Cadmium		320
Chromium		1,600
Copper		11,840
Lead		4,480
Manganese		64,000
Mercury		96
Nickel		6,400
Selenium		960
Silver		960
Thalium		22
Vanadium		2,240
Zinc		64,000
Radioactive Contaminants	pCi/g	
Gross Alpha		166
Gross Beta		40
Cesium-137		3
Cobalt-60		1
Uranium-235		15
Uranium-238		50
Other Inorganics	ppm	
Ammonium		310,400
Fluoride		19,200
Chloride		64
Nitrate		320,000
Organics	ppm	
Chloroform		0.24
1,2-Dichloroethylene		6,400
Methylene Chloride		0.3
Tetrachloethylene		2.04
Trichloroethylene		0.44

Table 2-2. Soil Washing System Description—Major Equipment. (sheet 1 of 3)

-
- Screen-All grizzly vibrating separator (2"): Trailer portable, diesel powered and self-contained fuel tank.
 - Feed hopper with variable speed metering belt conveyor.
 - Transfer belt conveyor from feed hopper to wet screen.
 - Double deck vibrating screen with high pressure water sprays (wet screen). Top deck 2mm, bottom deck not installed.
 - Wet screen sump with slurry pump.
 - Tower with 10" hydrocyclone.
 - Coagulant tank and supply pump.
 - Hydrocyclone overflow collection tank.
 - Flocculant make-up tank with mixer and supply pump.
 - Sludge settling tank with slow turning rake and water overflow to water storage tank.
 - Water storage tank with process water pump.
 - Two chamber attrition scrubber (used during uranium carbonate run only).
 - Dewatering screen (vibrating) with sump and water pump and with sand discharge belt conveyor.
 - Sludge holding tank with variable speed sludge recirculation pump.
 - Control room with control panel for soil wash plant.
 - Packaged filter press with integral controls, hydraulic system and with diaphragm type supply pump and water evacuation pump.
 - Sludge cake catch basin to collect filter press sludge cake before manual transfer to LSA containers.
 - Two (2) water reservoirs (6,000 gal. & 9,500 gal. piped together) for process water supply and dust suppression.

Table 2-2. Soil Washing System Description—Major Equipment. (sheet 2 of 3)

- One (1) horizontal water tank as a backup (not utilized).
- Gasoline fueled water supply pump with necessary piping, hoses and fittings.
- Water supply truck to refill water tanks as required.
- Fuel supply truck for generators, loaders and gasoline water pump.
- Loaders for feeding grizzly and plant feed hopper and for transferring process piles and weighing process piles. Note: three (3) different sized loaders were utilized during the runs.
- Portable (four (4) scales in series) system for weighing loader for soil wash feeds and products.
- 100 SCFM air compressor for filter press. Integral fuel tank, all on trailer.
- 150 KW 50 cycle 3 phase 380V generator for soil wash plant.
- 175 KVA 60 cycle 3 phase 460V generator for attrition scrubber, pulverizer, grinder and boiler.
- Fuel tank for generators with secondary containment catch basin.
- Field portable power distribution panel for feeds to auxiliary equipment.
- Cabling, hose, piping and connectors for all equipment process and electrical interconnects.
- Boiler system for process waste water evaporation including vertical water storage tower. Note: all of boiler system was not utilized for this project.
- LSA containers with liners for sludge cake holding and storage.
- Miscellaneous government vehicles for transportation of personnel and equipment.
- Various sized cranes for installations, repositioning and demobilizing the soil wash operations and associated systems.
- Office trailer.
- Change trailer with integral power generator.

Table 2-2. Soil Washing System Description—Major Equipment. (sheet 3 of 3)

- Lab trailer.
 - Portable toilet.
 - Sample preparation igloo.
 - 60 cycle 1 phase generator for office trailer and lab trailer.
 - Pulverizer for sample preparation.
 - Grinder for sample preparation.
 - Field/hand-held radiation monitoring instruments.
 - Anti-contamination clothing (anti-C's) and support service to keep clothing and supplies stockpiled.
 - Miscellaneous tools.
 - Sampling containers (many types and sizes) and associated equipment and supplies for sampling.
 - Screening trays for particle size separating.
 - Dust monitoring instruments.
 - First aid/safety equipment.
 - FM 2-way radios and cellular phones.
 - Log books.
-

3.0 RESULTS OF THE STUDY

3.1 PREPARATIONS FOR THE STUDY

ART began the preparations for the pilot study with coordination meetings and discussions with the WHC team. The dialogue encompassed the results of work previously performed at the site and the details related to support, and the responsibilities of the two parties. This work effort resulted in the preparation, review, and approval of the Soil Washing Separation Test Procedure (Test Procedure) and associated documents (ART 1994b). The Test Procedure included the details for the conduct of each of the test runs, the sampling and analysis program to be conducted, and the operational details for the running of the study. The Test Procedure is included as a reference document.

The ART/ATG team completed the Hanford Site training in February and March 1994, and all personnel working in the radiologically controlled area (RCA) were certified by March 10, 1994.

During early March, the pilot plant was erected at the ATG facility near the 300 Area and inspected by WHC for OSHA and site safety requirements. Minor modifications were performed on the pilot plant, and the plant was reinspected and approved for shipment to the 300-FF-1 North Process Pond.

On March 15, 1994, the plant was loaded by crane onto WHC trailers and transported to the staging area immediately adjacent to the North Process Pond. On March 16, 1994, the plant was moved into the surface contaminated area (SCA) at the North Process Pond. The plant was erected in the work area, the supporting services were installed and connected, and on March 28, 1994, the plant was ready to begin processing.

3.2 CHRONOLOGY OF STUDY PERFORMANCE

The chronology of major activities is shown in Table 3-1.

3.3 PROCESS SYSTEM DESCRIPTION

3.3.1 Process System Details

The system that was utilized to perform the test runs is described in this section. Prescreening was performed to remove the greater than 50-mm (2-in.) fraction. The process flow diagram of the system is shown in Figure 3-1. Photographs of the modular system are shown in Figures 3-2, 3-3, 3-4, and 3-5.

The separation process consists of the following steps:

- Prescreening at 50 mm
- Feeding at less than 50 mm
- Wet screening of the contaminated soil to separate the plant oversize fraction (between 2 mm and 50 mm)
- Separation of sand and fines by hydrocycloning
- Attritioning of the sand fraction (uranium carbonate run only)
- Dewatering of the sand fraction (hydrocyclone underflow)
- Flocculation and thickening of the fines fraction (hydrocyclone overflow)
- Dewatering of the sludge.

The soil washing system consists of seven units, which are described in the following sections.

3.3.1.1 Prescreening Unit. This unit consists of a mobile 50-mm vibrating screen provided and operated by ART. The purpose of this equipment is to remove coarse material larger than 50 mm as preparation for introduction of the soil into the soil washing plant.

3.3.1.2 Feeding Unit. This unit delivers the prescreened material to the wet screening unit. Soil introduced into the feed hopper is fed to the plant feed conveyor by the feed hopper conveyor. The feed hopper conveyor is equipped with a variable speed drive to regulate and adjust the feed rate to the system. The plant feed conveyor then delivers the feed to the wet screening unit.

3.3.1.3 Wet Screening Unit. This unit consists of a wet vibrating screen, a collection sump, and the hydrocyclone feed pump. The vibrating screen removes all coarse material larger than the selected screen deck size of 2 mm. Sprayers installed above the screen deck break down the soil and wash the oversized particles (> 2 mm). Pressurized wash water is obtained from the process water tank. The material passing the 2-mm screen forms a slurry that was collected in the slurry collection sump and pumped to the hydrocyclone.

3.3.1.4 Hydrocyclone, Sludge Settling Tank, Process Water Tank Unit. This unit contains the hydrocyclone, the hydrocyclone overflow collection tank, the process water tank, the sludge settling tank, and the attrition scrubber. Separation of the sand fraction from the contaminated fines fraction was achieved through the hydrocyclone. The system allows for changes in hydrocyclone configuration and operating conditions to achieve the desired separation performance. The "cut point," or separation size between the coarse-grained (sand) and fine-grained (fines) particles for the test runs, was targeted to be in the range of 0.075 mm to 0.150 mm. The diameter and sharpness of separation can be optimized by changing or reconfiguring the hydrocyclone to achieve a maximum separation of a "clean" sand product from the contaminated fines. To control hydrocyclone operation, a pressure-regulating pinch valve is

located after the hydrocyclone feed pump. To monitor hydrocyclone operation, a pressure indicator is located at the hydrocyclone inlet.

After hydrocyclone separation, a nonhazardous/nontoxic anionic flocculent (Aquafloc 477) was added to flocculate the fines. The flocculent was added in the hydrocyclone overflow line. To achieve good flocculation, for soils not containing the green uranium carbonate material, it was determined that the use of an additional coagulant was required. The selected nonhazardous, nontoxic cationic coagulant (Aquafloc 456C) was added in the dewatering sump to achieve a good dispersion of coagulant. The required flocculent and coagulant dosages to the process as determined in the flocculent testing was 20 ppm. During plant operation the flocculent dosage was adjusted (minimized) to achieve optimum process conditions.

The hydrocyclone overflow is collected in the hydrocyclone overflow tank and is directed to the sludge settling tank. The sludge settling tank allows for water clarification and settling of the fines. A slow-moving mixer at the bottom of the separator's cone prevents the sludge from "sticking." Clean water leaves the tank via an overflow launder and is collected in the process water tank. The sludge is collected at the bottom of the settling tank. The prethickened sludge is removed of the bottom of this tank via a manually operated valve and flows by gravity into the sludge holding tank.

For the uranium carbonate run, an attrition scrubber was used in line to break down the uranium carbonate present in surficially bound and agglomerate form in the sand fraction. The attrition scrubber was provided by WHC and was installed on top of the process water tank. When the attrition scrubber was used, the hydrocyclone underflow was directed into the scrubber and the discharge of the scrubber was fed directly onto the dewatering screen.

3.3.1.5 Sludge Holding Tank and Control Cabin Unit. This unit contains the sludge holding tank, the central control cabin for the plant, the process water pump, and a sludge recycling pump. From the sludge holding tank the sludge is pumped to the filter press for final dewatering of the fines. The pilot plant operation is controlled from the central control cabin. The filter press is controlled at the press.

3.3.1.6 Dewatering Unit. This unit contains the dewatering screen, a sand conveyor, the dewatering sump, and a recycle water pump. Dewatering of the hydrocyclone underflow (sand fraction) was accomplished through the use of the dewatering screen. The sand fraction was dewatered to about 80%-85% dry solids. The material passing through the dewatering screen was fed back to the wet screening unit.

3.3.1.7 Sludge Dewatering Unit. This unit contains the filter press, flocculent makeup tank, and the flocculent dosing pump. The filter press was used for final dewatering of the fines into a consolidated sludge cake. The sludge cake dry solids content varied from 43% to 63% and was collected in low specific activity (LSA) containers. The filtrate water from the filter press was recycled back to the sludge settling tank for reuse on the system. The flocculent used in the process was manually prepared in batches in the flocculent makeup tank and dosed to the process by the flocculent dosing pump.

3.4 OPERATIONS, DATA COLLECTION, AND ANALYSIS

3.4.1 Preprocessing

3.4.1.1 Soils Selection. The selection and excavation of contaminated soils were performed by WHC and ART. The areas of excavation are shown in Figure 3-6. Soils used for the pretest, verification, and replication runs were taken from the soils excavated from test pits A, B, and C. Selected materials were stockpiled near the screening area. The target amount of prescreened soils stockpiled was 300 tons. In addition, a target amount of 80 tons of soil containing the "green" material was taken from the excavated soils of test pits E, F, and G and stockpiled separately near the prescreening area.

3.4.1.2 Prescreening. Prescreening was performed using a mobile vibrating screen to remove coarse materials greater than 50 mm. The soils were directly fed onto the screen deck using a loader. The greater than 50-mm fraction was rejected to the side of the screen and the less than 50-mm fall-through material was collected underneath the screen. Fugitive dust was controlled by keeping the soils wet by water spraying onto the soils prior and during the prescreening. The amount of water used was restricted to the volume necessary to control dust formation while retaining the dry material handling characteristics.

The two selected source soils (with and without the "green" material) were screened separately. Prior to feeding the material onto the screen, each bucket load of material was weighed using a mobile weighing scale. Upon completion of the screening, the undersize (< 50 mm) fraction was weighed and the mass of the oversize (> 50 mm) fraction was calculated by difference. The less than 50-mm fraction for each of the source soils was then staged separately in a single feed pile near the feed hopper for introduction into the soil washing system. The weighing results and mass balances for the prescreening are presented in Tables 3-2 and 3-3.

3.4.1.3 Evaluation of the Gross Oversize. The purpose of the evaluation was to determine if significant concentrations of target constituents remain on the gross oversize fraction (particles > 50 mm) after the fraction had been separated by the mobile dry screening unit. The procedure for sampling the gross oversize is described in the Test Procedure (ART 1994b).

Pretest, Verification, and Replication Runs. Because all the material for the pretest, verification, and replication runs was processed at one time, separate piles of gross oversize were not generated. Instead, three composite samples were collected from material generated as the prescreening progressed. Each of the three composite samples was weighed (Table 3-4) and then washed by hand. Because of the large size of the particles, processing of the bulk material for chemical analyses could not be conducted. Therefore, it was necessary to hand wash the samples and collect the washed solids and wash water to facilitate analysis of this soil fraction after dry screening.

The level of wash water in each of the three polyethylene buckets was marked. The suspended solids in the wash water were then precipitated using both the selected coagulant (Aquafloc 456C) and a flocculent (Aquafloc 477) by adding approximately a milliliter of each reagent followed by hand mixing. The solids were allowed to settle, and the three samples of wash water were decanted into the laboratory containers. Any remaining wash water was

decanted and disposed by returning the wash water to the process water tank in the plant. Because the mass of settled and washed solids from each of the three individual samples was insufficient for all analyses (< 400 g), a composite sample was generated for analysis.

The weight of washed solids for the three samples was determined using an electronic decigram pan balance and is shown in Table 3-4. The volume of wash water was determined by refilling each of the three sample buckets with water to the same level as the wash water. The volume of water in each bucket was then measured using a 1-L graduated cylinder. The volumes are shown in Table 3-4.

The total mass of each constituent that could be removed from the three samples of gross oversize material was calculated in three steps. The calculations are outlined in Table 3-4. First, the mass contained in the wash water was determined by taking the concentration of the constituent in the wash water and then multiplying that concentration by the volume of water used in the washing step. Next, the mass of constituent in the washed solids was calculated by taking the constituent concentrations and multiplying them by the total mass of washed solids generated. Finally, the total mass of removable contaminant was determined by adding together the mass of each constituent present in the three wash water samples and the washed solids sample.

The concentration of removable constituents present in the gross oversize was then calculated by taking the total mass of removable constituent and dividing it by the total mass of the gross oversize material sampled. These results were then compared to the total concentration of the constituent in the gross oversize (as measured in the field by XRF) and to both the background for the site and the test performance criteria shown in Table 3-4.

For soils not containing "green" material, the concentration of removable constituents associated with the gross oversize was in all cases less than 0.2% of the test performance criteria.

Except for lead, the concentration of removable constituents from the gross oversize was much less than the site background values. The concentration of removable lead was calculated to be 6.21 mg/kg, whereas the background concentrations reported were 5.08 mg/kg and 1.55 mg/kg.

Based on this evaluation, prescreening using a mobile dry screening unit for soils that do not contain visible green material is sufficient to generate a product that meets the test performance criteria.

Uranium Carbonate Run. A single composite sample of gross oversize material (> 50 mm), generated from prescreening of soils containing the green uranium carbonate material, was collected as described in the Test Procedure (ART 1994b). The sample was washed, the solids precipitated, and the volume and masses of the washed products were measured as described above. The mass of the sample (HPGSL-8), the washed solids (HPGSL-9) and the volume of wash water (HPGWA-4) are presented in Table 3-5.

The total mass and concentration of removable constituents was also calculated as described above. The concentrations of removable silver, chromium, mercury, and nickel were slightly greater than either one or both of the background concentrations referenced. The

concentrations of removable copper and uranium were substantially greater than the reported background values. For soil containing "green" material, the concentration of removable constituents associated with the gross oversize was less than the test performance standards.

Although prescreening using a mobile dry screening unit was sufficient to generate a product that met the test performance criteria, the data also suggest that an appreciable load of copper and uranium may be recovered from this product during full-scale operations through the use of high-pressure water sprays to wash off impacted particulate materials that are easily removed.

3.4.1.4 Feed Characterization. As part of the preprocessing activities, ART planned to collect composite samples from the feed piles for the pretest, verification, replication, and uranium carbonate runs. These feed samples were designated for bulk analysis of uranium and total metals. Because only one feed pile was created for the pretest, verification, and replication runs, collection of three composite samples from the pile of materials was not appropriate. Instead, a composite sample for each run was collected by splitting the feed samples that were collected during each run. The results of the feed composite sample for the pretest run are shown in Table 3-6. The results of the feed composite samples for the other three runs along with the average concentrations for each of the feed samples are shown in Table 3-7. The particle size distribution of the pretest run composite is shown in Figure 3-7.

Of the constituents monitored, none of the constituents were present at a concentration greater than 10% of the test performance criteria in the replication and verification run feed soils. For the uranium carbonate run, uranium exceeds the test performance criteria in the feed and copper exceeds 10% of the test performance criteria. No other constituent in the uranium carbonate run feed material exceeded 10% of the test performance standard.

For constituents that are present at appreciable concentrations, the average concentration appears to agree well with the single analysis of the composite sample. However, for constituents that were present at lower levels in the verification and replication run, feed soils (silver, beryllium, cadmium, mercury, antimony, and zinc), the difference in the results exceeded two standard deviations from the average. Although the metals listed above were not the principal constituents detected in the uranium carbonate run feed soils, the higher concentrations reported in the composite sample agreed very well with the calculated average concentrations from the run.

3.4.1.5 Field XRF Analyses of the Feed Materials. According to the Test Procedure (ART 1994b) the composite feed samples discussed above were designated for field XRF analyses. In addition, the samples for the pretest and the uranium carbonate runs were scheduled to be screened into 11 particle size fractions followed by field XRF analyses of the fractions. As discussed earlier, the data from the work conducted by WHC in 1993 (DOE-RL 1994a) indicated that uranium was the principal constituent of concern and in fact was the only constituent that could be field screened by XRF that would be likely to exceed the test performance criteria shown in Table 2-1. Because copper was shown to be associated with the uranium in the impacted soils, the field XRF instrumentation was calibrated onsite for these two metals.

The instrument selected for use during the pilot study was a Spectrace Model 9000 Field Portable Energy Dispersive XRF. The calibration materials included National Bureau of Standards standard reference materials and standards prepared onsite using background soils as described in

the Test Procedure (ART 1994b). Although the instrument is factory calibrated for these 2 as well as over 20 other metals, the factory calibration factors were adjusted using the prepared standards to account for site-specific matrix effects. Therefore, the results for uranium and copper are considered the most reliable data and were used for onsite process monitoring and control. The data for these two metals are presented in their entirety in Chapter 4.0 in conjunction with a discussion of the instrument's comparability to offsite laboratory analyses.

The copper and uranium results of the field XRF analyses for the pretest fraction analysis are shown in Table 3-6. As indicated in the table, the concentration of copper in the samples generated from the fraction analysis increased substantially, from less than 75 mg/kg to 725 mg/kg, and the concentration of uranium increased from less than 8 pCi/g to 19 pCi/g.

As shown in Table 3-6, the concentration of uranium in each of the fractions was below the test performance criteria (50 pCi/g), and furthermore, uranium was not detected in any fraction with a particle size greater than 0.075 mm. Because of the low concentrations of uranium, the concentrations reported for copper were used as surrogate data in selection of the pilot plant operating conditions.

According to the data presented in Table 3-6, the concentration of copper increases gradually with decreasing particle size. However, due to the small mass of material in the fractions with particle sizes 0.045 mm and 0.425 mm, the distribution of the mass of copper is very low in this range of particle sizes (approximately 3% or less per fraction). Therefore, the selection of a specific cut point in the range 0.045 mm to 0.425 mm would not be governed principally by the distribution of the chemical constituents. However, expecting that the sludge generated by the system would be approximately 50% solids (based on professional experience), selection of a cut point at 0.075 mm would generate a sludge (<0.075 mm) that would constitute approximately 5% by weight of the plant feed material on a dry-weight basis (4.6% plus 0.5% from Table 3-6) and approximately 10% of the plant feed material on a wet-weight basis. Taking into account the mass of gross oversize from Table 3-2, the wet sludge at a 0.075-mm cut point was estimated to constitute 7% of the gross feed yielding an anticipated 93% reduction in mass. Consequently, to obtain a 90% reduction and maintain a 3% safety factor, the effective cut point for treatment of copper and uranium was selected to be 0.075 mm.

Field XRF analysis of the fractions generated from the composite sample of the uranium carbonate run feed were not required and consequently were not conducted for the following reasons. The experience gained during plant operations for the verification and replication runs indicated that the plant operated very efficiently at a 0.075-mm cut point. Also, the results of the initial particle size analysis of the uranium carbonate run feed material indicated that the plant feed material contained a higher percentage of fines than the feed material used during the verification and replication runs. Therefore, to maintain a reduction near 90%, the cut point could not be increased. However, because only a small percentage of soils were present between 0.150 mm and 0.075 mm, leaving the cut point at 0.075 mm would minimize the amount of fines (which were anticipated to be highly contaminated) present in the sand product. Therefore, to maintain as high a percent reduction as possible while balancing the importance of minimizing contaminated material in the sand, the decision was made to use a 0.075-mm cut point. Consequently, the hydrocyclone and associated operating conditions were dictated by factors other than the chemical distribution in the soils, and the field XRF analyses of the feed material fractions were not conducted prior to the run.

3.4.2 Pretest Run

3.4.2.1 Description. The pretest run was conducted on March 29, 1994. The purpose of the pretest run was to adjust the plant process water flows, soil feed rate, and flocculent dosage rates; to select the operating conditions including the hydrocyclone to be used, the hydrocyclone inlet pressure, and the dewatering screen configuration for the verification and replication runs; and to identify any potential problems. In the pretest run two tests were performed with different hydrocyclone configurations to produce two different cut points. As feed material for the pretest run, prescreened soil containing material less than 50 mm (not containing visually identifiable "green" material) was used. Water used to perform the pretest run was clean water obtained from the onsite freshwater tanks.

Pretest 1. Pretest 1 was designed to have a target cut point of 0.075 mm for separation between the sand and fines fractions. In pretest 1, a total of 16.4 tons of prescreened soil was processed during a total of 1 h and 53 minutes of processing time. The average feed rate during the test was 8.7 tons/h.

During performance of the test, mechanical problems occurred with respect to the feeding of the soil from the feed hopper onto the plant feed conveyor. Because of the large amount of cobbles and coarse gravel material present in the Hanford soil, problems were encountered with the feed unit. Occasionally, a sudden discharge of material onto the plant feed conveyor occurred that caused overfeeding of the wet screening unit. By the end of pretest 1, gravel had built up in the sump under the wet screen as a result of overfeeding the wet screen and had blocked off the flow to the hydrocyclone. At this point, all samples were collected and the test was stopped.

Pretest 2. Pretest 2 was designed to have a target cut point of 0.125 mm to 0.150 mm for separation between the sand and fines fractions. In this test a total of 16.9 tons of prescreened soil was processed during a total of 1 h and 6 minutes of processing time. The average feed rate during the test was 15.4 tons/h.

To control the feeding problems with the feed hopper for this run, the hopper feed gate was only slightly opened and feeding of the material was continuously assisted and manually guided by field personnel. The feed to the soil washing plant could be controlled, and the problems due to overfeeding could be prevented in this manner.

Products Weighing/Mass Determination. For both pretest runs, the process feed material and process products were weighed using a loader and four mobile field weighing scales. Net weights for each load were determined by calculating difference between the gross weight of the loader with the product minus the net weight of the empty loader.

Problems were encountered in the field with respect to reproducing some of the measured weights. These problems are discussed in detail in Section 4.5.

Because of the initial problems of weighing the products of the pretest run, the weighing results should be considered estimated values. For continued weighing during the actual runs, the weighing procedure was changed to improve reproducibility of the readings. The methods of mass determination for each of the products is briefly described in the following paragraphs.

Weighing of Plant Feed. Each bucket load of material fed to the soil wash system was weighed prior to introduction into the feed hopper. The total net mass of less than 50-mm feed material processed was 16.4 tons for pretest 1 and 16.9 tons for pretest 2.

Weighing of Oversize Product. After completion of the processing, the oversize product was collected by the loader and weighed. Although a good effort was made to collect all of the product, some material could not be recovered due to scraping and pushing of the loader. The total estimated mass as determined was 10.5 tons for pretest 1 and 9.4 tons for pretest 2.

Weighing of Sand Product. After completion of the processing, the sand product was collected by the loader and weighed. Although a good effort was made to collect all of the product, not all material could be collected by the loader. The total estimated mass as determined was 3.1 tons for pretest 1 and 2.3 tons for pretest 2.

Weighing of Sludge Product. After completion of filter press operations, the combined sludge product of pretests 1 and 2 was collected in two LSA containers. These containers were weighed after completion of the run by use of a mobile crane equipped with a load scale. The net weight was determined by subtracting the known tare weight for each of the LSA containers from the total weight measured. The total net mass of sludge product was determined to be 2.9 tons.

3.4.2.2 Process Products Analysis. For both pretest runs the process products were analyzed to provide preliminary information with respect to whether the performance standards for the test have been met and to determine initial particle size distribution analysis data for plant feed, process oversize, and clean sand. For both pretests, particle size distribution data are summarized in Table 3-8. The calculated hydrocyclone separation efficiencies for both sand products are summarized in Table 3-9.

By comparing the hydrocyclone separation efficiencies for each size fraction, it was confirmed that pretest 1 gave higher recovery efficiencies for the finer fractions as compared to pretest 2 while the performance standards were met for both pretest sand products (Section 3.4.2.3). Based on these results, a 0.075-mm cut point and an approximate feed rate of 15 tons/h as used in pretest 1 were selected to perform the verification and replication runs. Through selection of the finest cut point, the total mass of contaminated process residuals resulting from the soil washing process were minimized and recovery of a clean product optimized.

3.4.2.3 Chemical and Radiological Analysis. As discussed above, the pretest run was conducted in two parts using two different hydrocyclone configurations, pretest 1 and pretest 2. When compared with pretest 1 (0.075-mm separation), the performance of the hydrocyclone during pretest 2, configured to separate the particles at approximately 0.150 mm, had significant misplacement of particles greater than 0.150 mm in the fines. On the basis of plant efficiency, pretest 1 conditions were preliminarily selected for use during the subsequent test runs. Products generated during pretest 1 were subjected to particle size and field XRF analysis.

Bulk Analyses of the Feed Material and Process Products. In accordance with the Test Procedure (ART 1994b), ART analyzed samples of the feed material, process oversize, clean sand products, and contaminated fines from the selected run, pretest 1. The results of the field XRF analyses for copper and uranium of the bulk feed material and plant products are shown in

Table 3-10. In addition, samples of the feed material, oversize, clean sand, and fines were sent to PNL for XRF analysis as confirmation. A summary of the results of the analyses conducted by PNL are shown in Table 3-11.

As shown in Table 3-10, the copper present in the feed material was concentrated to the fines by a factor greater than six. The data generated by PNL for copper confirmed the field XRF data. For uranium, partitioning of the constituent in the fines by a factor of two was observed; however, the PNL data did not confirm a difference in the concentration of uranium between the feed material and the fines. However, the sets of analyses indicated that the oversize material contained substantially less copper and uranium than the feed or other products.

Fraction Analysis of the Feed Material and Process Products. A composite sample of the feed material, process oversize, and clean sand were subjected to particle size analysis and subsequent analysis of the particle size fractions by field XRF. The data for these analyses are shown in Table 3-6. The expected concentrations of copper and uranium in the bulk samples as calculated from the analysis of the particle size fractions are also shown. The results of the particle size fractions generate a calculated bulk concentration (feed material: 116 mg/kg copper, 5 pCi/g uranium; process oversize 40 mg/kg copper, 4.2 pCi/g uranium; and clean sand 126 mg/kg copper, 4.4 pCi/g uranium) that is similar to but, for copper, about 15% to 25% less than the average bulk concentrations that were measured (feed material: 134 mg/kg copper, <8 pCi/g uranium; process oversize <75 mg/kg copper, <8 pCi/g uranium; and clean sand 165 mg/kg copper, <8 pCi/g uranium).

When compared to the fraction analysis conducted as part of the preprocessing effort, the constituent concentrations within the feed material show a similar pattern. Concentrations of copper increased with decreasing particle size. Likewise, the mass of copper in the fractions is lowest in the particle size range of 0.075 mm to 0.425 mm. This low mass distribution is a result of the reduced mass of particles in this size range, despite the increasing concentrations of copper in the fractions. Although some variations in particle size and constituent concentrations were noted, the preprocessing feed sample and the pretest feed sample produced similar results, thereby further supporting the operating decisions that were based on the preprocessing feed sample results.

As discussed earlier, the separation efficiency of the 2-mm screen was 97.7% for the process oversize produced. The concentration of misplaced material in the process oversize fraction (>2.0 mm) included 92 mg/kg copper in the 0.425-2.0 fraction and 563 mg/kg copper in the <0.425 fraction. Uranium was not detected in the misplaced materials. Although the concentration of copper in the misplaced fractions is high compared to the concentration of copper in the bulk sample (<75 mg/kg), the mass of copper in the misplaced fractions constitutes less than 8% of the total copper present in the process oversize product.

Likewise, the separation efficiency of the hydrocyclone (configured to separate particles at 0.075 mm) was quite high at 97.5%. The concentration of misplaced material in the clean sand fraction (0.075 mm to 2.0 mm) included 388 mg/kg copper in the 0.045- to 0.075-mm fraction and 1,027 mg/kg copper and 17 pCi/g uranium in the <0.045-mm fraction. These concentrations are significantly greater than the concentrations of the metals in the bulk material, 165 mg/kg copper and <8 pCi/g uranium. Again, because of the high separation efficiency of the plant, the misplaced materials only constituted 16% of the total copper and 7% of the uranium in the clean sand product.

Data Evaluation. The particle size analyses, field XRF data, and the confirmatory analyses conducted by PNL indicated that a cut point of 0.075 mm would ensure that the process oversize and clean sand stream would meet the test performance criteria, while providing a mass reduction on both a wet- and dry-weight basis of over 90%.

The results of the PNL analyses of the feed material, process oversize, and fines were used to determine if field XRF analysis of metals in addition to uranium and copper was warranted. As seen in Table 3-11, of the constituents detected only uranium was present in the feed material at a concentration greater than 10% of the test performance criteria. Based on the data from PNL, continued process monitoring for only copper and uranium appeared necessary for subsequent runs.

3.4.3 Verification Run

3.4.3.1 Description. The purpose of the verification run was to verify that a water-only physical separation soil washing process could achieve a minimum volume reduction of 90% by weight for processed soil fractions meeting the test performance criteria.

The verification run was conducted on April 6, 1994. As feed material for the verification run, the same prescreened soil (not containing visually identifiable "green" material) used in the pretest run was processed in the pilot plant. Based on the results of the pretest run, the primary operating conditions used in pretest 1 were selected for the verification run, a cut point of approximately 0.075 mm, and a feed rate of approximately 15 tons/h. For the verification run, the attrition scrubber was not used as part of the system.

For the verification run, a total of 79.8 tons of less than 50-mm soil material was processed during a total of 4 h and 44 minutes of processing time. The average feed rate during the test was 16.9 tons/h. As process water for the verification run, the process water retained in the system after completion of the pretest run was used.

During performance of the verification run, special attention was paid to control plant feed. Feeding was manually assisted with shovels to prevent blocking off the feed hopper gate and keep the feed as constant as possible. During the first 1.5 h of processing time, problems occurred with respect to pumping of the coagulant due to high product viscosity. Due to the inability to add the coagulant during this time, optimal flocculation did not occur and fines were carried over into the recycling water. After approximately 1.5 h into the run, the pumping problems were solved yielding satisfactory flocculation and substantially improved recycled water quality.

Field Weighing/Mass Determination. As discussed in detail in Section 4.5, the results of the process product weighing performed during the prescreening and pretest run indicated that the net weight of feed materials and process products were extremely sensitive to the positioning of the scales. To minimize the effect of misalignment of the scales, the scales were carefully repositioned for each weighing event. Repositioning of the scales resulted in good reproducibility of the readings. This improved weighing procedure was used to weigh all

products of the verification run and the subsequent replication and uranium carbonate runs. A summary of field weighing results and process product mass balance for the verification run is presented in Table 3-12. The methods of mass determination for each of the products are briefly described in the following paragraphs.

Weighing of Plant Feed. Each bucket load of material fed to the soil wash system was weighed prior to introduction into the feed hopper. The total net mass of less than 50-mm feed material was 79.8 tons.

Weighing of Oversize Product. After completion of the processing the oversize product was collected by the loader and weighed. Although a good effort was made to collect all of the product, some material was lost on the ground due to scraping and pushing of the loader. The total estimated mass as determined was 62.9 tons.

Weighing of Sand Product. After completion of the processing, the sand product was collected by the loader and weighed. Although a good effort was made to collect all of the product, not all material could be collected by the loader. The total estimated mass was 16.0 tons.

Weighing of Sludge Product. After completion of filter press operations, the sludge product was collected in two LSA containers. These containers were weighed after completion of the run by use of a mobile crane equipped with a load scale. The net weight was determined by subtracting the known tare weight for each of the LSA containers from the total weight measured. The total net mass of sludge product was 6.3 tons.

3.4.3.2 Process Products Analysis. During the first and last sampling events of the verification run, samples of feed soils, process oversize, sand, and fines were collected for soil particle size distribution analysis. Particle size analysis of the recycled water was not required. Results of these particle size analysis are summarized in Table 3-13, and the data for the feed samples are shown graphically in Figure 3-8.

For each of the process products, the system separation efficiency has been determined. The separation efficiency is defined as the material of the specific size fractions that should be in process product as a percentage of total material in process product.

For each of the process products, high separation efficiencies were achieved from 95% on average for the sludge fraction, 97.2% on average for the sand, and up to 99.5% on average for the oversize fraction. These high separation efficiencies indicate a highly effective separation performance for all products generated by the soil washing system.

Using the particle size distribution data and correcting for the amount of gross oversize (fraction > 50 mm), the original soil particle size distribution for the unscreened soils (including material > 50 mm) has been calculated and is shown in Table 3-14.

3.4.3.3 Chemical and Radiological Analysis. Consistent with the Test Procedure (ART 1994b), samples of the feed material, process oversize, clean sand, fines, and recycled water were collected approximately every 30 minutes during plant operations. A total of nine sampling events were completed, and the samples were analyzed for metals and total uranium, with the first and last sample from each of the materials analyzed for metals, isotopic uranium, and a

gamma scan. The recycled water samples were also analyzed for volatile organic constituents (VOCs) and total solids. The results of the analysis of these samples for metals and radionuclides are summarized in Table 3-15; the results of the analysis of the recycled water for VOCs and total solids are presented in Table 3-19.

Bulk Analyses of the Feed Material and Process Products. As shown in Table 3-15, all the constituents were present in the plant feed at an average concentration less than 10% of the test performance criteria. As noted in the table, total uranium concentrations were converted from milligrams per kilogram to picocuries per gram as uranium-238. The contribution of uranium-235 to the total uranium concentration is estimated to be 0.7% of the mass of total uranium. Also for the purposes of this report, results reported as less than values (<) were assumed to be equal to one-half the indicated detection limit in all statistical and mass balance calculations. Of the radionuclides identified in the Phase III feasibility study (DOE-RL 1994b) as contributing to the risks at the North Process Pond, radium-226 and zinc-65 are not discussed in the following sections because radium-226 was not required to be monitored during the pilot study and zinc-65 was not detected in any of the samples collected.

Cadmium was not detected and mercury was detected in only four of the nine feed samples. The average aluminum (5,702 mg/kg) and lead (3.5 mg/kg) concentrations in the feed material were below values previously reported as background concentrations. The average concentrations of silver (2.3 mg/kg), beryllium (0.82 mg/kg), iron (40,189 mg/kg), manganese (466 mg/kg), and zinc (51.5 mg/kg) in the feed material fell within two times concentrations previously reported as background. The average feed concentrations of antimony (11.4 mg/kg), copper (145 mg/kg), chromium (50.2 mg/kg), and nickel (28.7 mg/kg) were between two and eight times the highest reported background concentrations.

The average uranium concentration (1.5 pCi/g) of the feed was above the reported background of 0.6 pCi/g (WHC 1994). Traces of cesium-137 (0.04 pCi/g) and cobalt-60 (0.05 pCi/g) were detected in the feed samples. Thorium-228 (0.474 pCi/g) and potassium-40 (10.9 pCi/g) were also detected in the feed material at trace activities. Background activities for these naturally occurring isotopes are 0.687 and 14.2 pCi/g (WHC 1994).

For those constituents detected in the feed material, the process oversize samples contained lower concentrations/activities of the metals and radionuclides. As shown in Table 3-15, of the metals analyzed, silver and copper concentrations in the process oversize were approximately one-fourth of the concentrations present in the feed material. The concentrations of the remaining metals were approximately two-thirds to three times less than the concentrations in the feed material. Of the radionuclides monitored, the concentrations/activities of uranium in the process oversize were reduced by a factor of four compared to the feed material while the activities of cesium-137 and cobalt-60 were reduced to levels below the minimum detectable activities. However, the activity of thorium-228 was reduced by only 10%, and the activity of potassium-40 was reduced by 0.1 pCi/g or about 1%.

The data in Table 3-15 show that, except for lead (3.5 mg/kg feed material to 3.9 mg/kg clean sand), the concentrations of each of the metals in the clean sand was less than the concentration reported in the feed material. However, with the exception of chromium (from 17.7 mg/kg in the process oversize to 9.7 mg/kg in the clean sand), the concentrations reported in the clean sand were greater than the concentrations reported in the process oversize. Except for thorium-228 and potassium-40, the activities of the radionuclides in the clean sand were

slightly greater than the activities reported in the feed material. Similarly, the activities of all the radionuclides except potassium-40 were greater in the clean sand than in the process oversize. In the absence of substantial amounts of waste material, the reduction in particle size of the clean sand fraction versus the process oversize was expected to produce generally increased concentrations of metals compared with the values reported in the process oversize.

As expected, the data for most of the metals and radionuclides in Table 3-15 show an increase in the concentrations in the fines compared to the feed material, process oversize, and clean sand. Of the constituents monitored, only the radionuclides uranium-238 and cobalt-60 were present in the fines at activities within 10% of the test performance criteria.

The average concentrations of antimony, beryllium, and iron in the fines decreased when compared to the feed material, while the concentrations of chromium, manganese, and zinc along with the activities of potassium-40 and thorium-228 increased slightly, by a factor of two or less. The decreased concentrations in the fines or slight increases are consistent with the fact that these eight constituents are not known to have been significant components of the wastes managed at the site. As such, the concentrations/activities reported are principally associated with the natural abundance of these materials in the soil/mineral matrix. Therefore, the concentrations/activities were not expected to show a substantial increase with decreasing particle size.

The average concentrations of cadmium (1.0 mg/kg), nickel (96.6 mg/kg), and aluminum (24,656 mg/kg) showed approximately a four-fold increase in concentration when comparing the fines to the feed material. For nickel and cadmium, the data indicate that these two metals may have been components of the wastes managed at the site. However, at the concentrations noted, the average concentrations of cadmium and nickel are still less than 1% the test performance criteria. Aluminum is a significant component of the sludges found at the site. However, the presence of natural aluminum in the soil/mineral matrix contributes significantly to the concentration of aluminum in the feed soil, while the concentration of natural aluminum (assuming a reasonably consistent natural concentration) would constitute a smaller portion of the aluminum in the fines. If the natural background of aluminum were known with greater certainty, subtraction of the natural aluminum from the disposed aluminum would likely demonstrate a concentration factor of disposed aluminum in the feed soils to fines of much greater than four.

The remaining metals and radionuclides exhibited concentration factors for the average concentration/activities from the feed material to the fines ranging from over 6 for copper and cesium-137 to approximately 30 for mercury. However, of the remaining metals and radionuclides, the concentrations of copper (972 mg/kg), silver (18.2 mg/kg), mercury (1.4 mg/kg), lead (36.5 mg/kg), and the activity of cesium-137 (0.292 pCi/g) in the fines ranged from about 10% to less than 1% of the test performance criteria. Only uranium-238 (19 pCi/g) and cobalt-60 (0.718 pCi/g) occurred in the fines fraction at approximately 40% and 70% of the test performance criteria, respectively.

Fraction Analysis of the Feed Material and Process Products. Because copper, uranium-238, cesium-137, and cobalt-60 are known to be associated with the waste, these constituents showed concentration factors in the fines approaching 10 or greater when compared to the feed, and none of the other constituents had concentrations/activities in the feed approaching the test performance criteria, the discussion of contaminant removal ideally would focus on these four constituents. However, the scope of work provided by WHC did not require

analysis of cobalt-60 or cesium-137 in the particle size fractions; therefore, the discussions of system efficiencies and contaminant distribution with particle size will be confined to copper and uranium.

The discussion of uranium focuses only on uranium-238 based on three factors: (1) the activity of uranium-235 in reactor fuels compared to uranium-238 is approximately 7% or less; (2) the test performance criteria for uranium-235 is 30% of the test performance criteria for uranium-238; and (3) the Phase III feasibility study (DOE-RL 1994b) identified uranium-238 as the principal risk driver for the North Process Pond. Therefore, when uranium-238 exceeds the test performance criteria (15 pCi/g), the activity of uranium-235 would be approximately 1 pCi/g, which is only 20% of the standard for uranium-235 (5 pCi/g). Therefore, in the absence of uranium enrichment that is atypical for reactor fuels, uranium-238 would appear to be the controlling constituent. This is also consistent with the findings of the Phase III feasibility study (DOE-RL 1994b) with respect to the North Process Pond.

During the first and the ninth sampling events of the verification run, an additional aliquot of sample was collected of the feed material, process oversize, and clean sand. The sample aliquots were sent to PNL for particle size analysis. The fractions from the particle size analysis were submitted to Roy F. Weston Laboratory for analysis of metals and total uranium. Chemical and radiochemical analysis of the fractions generated by particle size analysis of the fines was not required. The results of the analyses of the particle size fractions generated from the feed material, process oversize, and clean sand are also shown in Table 3-16. The results of the copper and uranium analyses separated by particle size are shown in Tables 3-17 and 3-18 and are shown graphically in Figures 3-9 and 3-10.

A comparison between the bulk concentrations of the feed material, process oversize, and clean sand discussed in Section 3.4.3.3, and the total concentrations of copper and the total activities of uranium as calculated from the analysis of the various particle size fractions provides an indication of the internal consistency of the data. The concentrations of copper in the two feed samples as reported by the laboratory were 102 mg/kg and 108 mg/kg and compared well to the calculated concentrations of 124 mg/kg and 109 mg/kg. A similar correlation for the measured and calculated copper concentrations in the clean sand (120 and 107 mg/kg versus 144 and 138 mg/kg) was noted. However, the correlation between the measured and calculated concentrations of the process oversize (62.6 and 31.3 mg/kg versus 41 and 49 mg/kg) did not give as good agreement. The deviations in the process oversize evaluation are likely a result of the difficulty in obtaining homogeneous samples of the coarse materials which could have significantly different copper content.

The average efficiencies of the 2-mm wet screen and the hydrocyclone (set to separate particles at 0.075 mm) were 99.5% and 97.2%, respectively. The concentration of copper in the misplaced less than 2-mm material present in the oversize product from the wet screen was 139 mg/kg, while the concentrations of copper in the two misplaced fine fractions (0.045-0.075 mm and <0.045 mm) present in the sand product ranged from 346 mg/kg to 1,460 mg/kg. Although these concentrations are substantially greater than the bulk concentrations, the misplaced material led to only a 1.5% increase in the copper in the process oversize product and to an average increase of 16.5% in the concentration of copper in the clean sand due to the misplaced fines fractions. A similar evaluation for uranium indicated that the misplaced material in the process oversize constituted only 0.5% of the uranium activity in the

fraction while the misplaced material in the clean sand fraction contributed 19.6% of the uranium activity.

Bulk Analysis of the Recycled Water. The operational problems with the coagulant pump, which were discussed in Section 3.4.3.1, had a significant effect on the quality of the recycled water collected during the first three sampling events. As shown in Table 3-19, the total solids concentration (8,880 to 16,700 mg/L) as well as the concentration of metals in the recycled water increased during the first 1.5 h of operation. Several metals including copper (20,700 $\mu\text{g/L}$), manganese (11,200 $\mu\text{g/L}$), iron (14,600 $\mu\text{g/L}$), nickel (1,750 $\mu\text{g/L}$), and aluminum (114,000 $\mu\text{g/L}$) as well as uranium (1,400 $\mu\text{g/L}$) were present at maximum concentrations above 1,000 $\mu\text{g/L}$.

The modifications to the water treatment system were effective in improving the recycled water quality. The concentration of total solids in the last six samples of recycled water varied from 224 mg/L to 492 mg/L. The concentrations of metals also were significantly reduced with only aluminum (1,301 $\mu\text{g/L}$) and iron (1,362 $\mu\text{g/L}$) having average concentrations above 1,000 $\mu\text{g/L}$. Because the results of the first three sampling events are not representative of the plant operation due to the high solids loading experienced before the water treatment system became fully functional, the average concentrations shown in Table 3-15 and Table 3-19 are calculated from the constituents detected in only the last six sampling events.

A similar pattern was noted in the review of the isotopic uranium and gamma analyses of the recycled water samples collected. The first sample HVRWA-001 contained cobalt-60 (6.95 pCi/L), cesium-137 (6.45 pCi/L), potassium-40 (153 pCi/L), thorium-228 (13.4 pCi/L), uranium-235 (9.6 pCi/L), and uranium-238 (180 pCi/L). Only uranium-238 (5.2 pCi/L) and potassium-40 (85 pCi/L) were detected in the last sample.

As shown in Table 3-19, the initial makeup water for the plant contained low levels of trihalomethanes (THMs) including chloroform. These constituents would be expected to be present in a chlorinated potable water supply. The recycled water samples collected during the verification run did not contain any detectable concentrations of VOCs, indicating that the original THMs were removed from the water system, probably through volatilization, and that the VOCs suspected to be present in the soils were not transferred into the recycled water.

3.4.3.4 Contaminant Removal, Mass Balance, and Volume Reduction.

Contaminant Removal. Using the mass balance on a dry-weight basis as shown in Table 3-12 and the average concentration/activity of uranium-238 and cobalt-60 in the feed material and fines as shown in Table 3-15, a percent removal of these two constituents was calculated. The process removed 80% of the cobalt-60 and 68% of the uranium. Because copper and cesium-137 are known to be associated with the waste managed at the site, the percent removal of these two constituents was also calculated. The process removed 36% of the cesium-137 and 35% of the copper.

As indicated in Table 3-17, the mass of copper in the samples of the feed material subjected to particle size analysis is distributed approximately 40% in the fraction greater than 2 mm (process oversize), 20% in the fraction between 0.075 and 2 mm (sand), and 40% in the fraction less than 0.075 mm (fines). This distribution compares well with the 35% removal calculated for copper in the bulk fines, which was discussed earlier.

The graphical representation of the copper distribution data for the feed material, shown in Figure 3-9, indicates that a separation point in the range of 0.425 mm and 0.045 mm would result in removal of a significant mass of both constituents while obtaining a 90% or better mass reduction. Using the data from the initial sampling event as an example, it should be noted that by including particle sizes above 0.045 mm the removal of copper increases from 34.2% to 42.4% (a 25% increase in mass removed). However, by choosing a higher separation point (0.425 mm), the mass of the fines destined for disposal increases from 4.5% to 9.4%, a more than two-fold increase in the mass of material designated for offsite disposal.

Mass Balance. The process product mass balance for the verification run is presented in Table 3-12 and Figure 3-11. The dry mass solids recovery for the total run was 101%, indicating a good closure of the mass balance. Based on the original soil particle size distribution, the fractional distribution of gross oversize (> 50 mm), process oversize (2.0 - 50 mm), sand (0.075 - 2.0 mm), and fines (<0.075 mm) have been calculated and compared to the fractional distribution of the field test. The results of the calculated fraction distribution and actual fraction distribution for the run are summarized in Table 3-20, and a graphical comparison is shown in Figure 3-12. The good comparison between calculated and measured fraction distribution for the verification run indicates the data are internally consistent. Based on results of the field test, the original soils used for the verification run contained approximately 27% gross oversize (> 50 mm), 56% process oversize (2.0 - 50 mm), 13% sand (0.075 - 2.0 mm), and 3.7% fines (<0.075 mm) on a dry-weight basis.

Volume Reduction. The volume reduction by weight for the verification run has been calculated based on the total mass balance (including the fraction > 50 mm) data as summarized in Table 3-21. The feed and sludge product were directly weighed, while the sand and oversize are weighed products, plus an estimate for "on-ground" losses was added. The "on-ground" losses do not affect the calculations of the volume reduction. The volume reduction by weight has been calculated using the following formula:

$$\text{Volume Reduction by Weight (\%)} = \frac{(A-D-E_{sw}) \times 100}{A}$$

- A - Total tons processed (including > 50-mm material)
- D - Total tons of contaminated material
- E_{sw} - Total tons of secondary waste.

Total Tons Processed (A). The total tons processed refers to original soil including material greater than 50 mm. Since the soils were prescreened at 50 mm prior to processing, the fraction of greater than 50-mm material corresponding with the amount of minus 50-mm plant feed needs to be included for the determination of the volume reduction by weight. The plus 50-mm fraction corresponding with the amount of minus 50-mm plant feed was calculated using the ratio of plus 50-mm fraction versus minus 50-mm fraction as determined in the prescreening. The sum of the minus 50-mm plant feed processed through the soil washing system and calculated fraction of plus 50-mm fraction constitutes the total tons processed of original soil for this run.

Total Tons of Contaminated Material (D). For the soil washing process, the only contaminated fraction generated was the sludge cake product. The total mass of the sludge

product for this run as produced and weighed in the field has been used for calculation of the volume reduction by weight.

Secondary Waste (Esw). For each of the runs performed, the process water was recycled and reused to perform the next run. The purpose of reusing the process water for each of the runs was to demonstrate the technical feasibility of reuse of the process water in the soil washing system. Reuse of the process in the runs also better reflects the approach that would be taken in full-scale processing in which case the process water will be completely recycled back into the system. Buildup of dissolved uranium and other contaminants may be controlled through additional treatment to remove dissolved contaminants prior to water reuse. However, treatment of the water through evaporation, as originally planned, would not be practical and/or economical and would not be considered for full-scale treatment. Therefore, in full-scale soil washing operations, no secondary waste will be generated through evaporation. In order to quantify secondary waste consisting of dissolved and suspended solids associated with the process water in the system after all the runs were performed, the following calculations were used:

$$Esw \text{ (tons)} = TSp * Vp * (2.2/2.0) * 10^{-9}$$

Esw	-	Total tons of secondary waste (tons)
TSp	-	Total solids in process water (mg/L)
V _p	-	Total volume of process water (L).

Based on 652 mg/L of total solids as analyzed in the process water at the end of the uranium carbonate run, an estimated volume of process water in the system of 1,800 L, the total amount of secondary waste for all runs was calculated to be:

$$Esw = 652 \times 18000 \times (2.2/2.0) \times 10^{-9} = 0.013 \text{ tons}$$

Based on this analysis, the amount of secondary waste consisting of dissolved and suspended solids was insignificant and could be neglected for the mass balance evaluation for each of the runs.

Based on the results of the verification run and using the data as summarized in Table 3-21, the volume reduction by weight was determined to be:

$$\text{Volume Reduction by Weight (Verification Run)} = 94.3 \%$$

3.4.4 Replication Run

3.4.4.1 Description. The purpose of the replication run was to replicate the results of the verification run.

The replication run was conducted on April 11, 1994. As feed material for the replication run, the same prescreened soil (not containing visually identifiable "green" material) as used for the verification run was processed. For the replication run, the operating conditions

of the verification run were used except that the target feed rate was adjusted to 10 to 12 tons/h. The plant arrangement was the same as for the verification run.

For the replication run, a total of 52.1 tons of less than 50-mm soil material was processed during a total of 5 h and 45 minutes of processing time. The average feed rate during the test was 9.1 tons/h. As process water for the replication run, the process water retained in the system after completion of the verification run was used.

During performance of the replication run, special attention was paid to feed control. Feeding was manually assisted with shovels to prevent blocking of the feed hopper gate and to keep the feed as constant as possible. This run was completed without any processing problems or process upsets.

Field Weighing/Mass Determination. For weighing of the process products, the same weighing procedures were used as were used for the verification run. A summary of field weighing results for the replication run is presented in Table 3-22. The methods of mass determination for each of the products is briefly described in the following.

Weighing of Plant Feed. Each bucket load of material fed to the soil washing system was weighed prior to introduction into the feed hopper. The total net mass of less than 50-mm feed material was 52.1 tons.

Weighing of Oversize Product. After completion of the processing, the oversize product was collected by the loader and weighed. Although a good effort was made to collect all of the product, some material was lost on the ground due to scraping and pushing of the loader. The total estimated mass was 40.2 tons.

Weighing of Sand Product. After completion of the processing, the sand product was collected by the loader and weighed. Although a good effort was made to collect all of the product, not all material could be collected by the loader. The total net mass as determined was 10.9 tons.

Weighing of Sludge Product. After completion of filter press operations, the sludge product was collected in two LSA containers. These containers were weighed after completion of the run by use of a mobile crane equipped with a load scale. The net weight was determined by subtracting the known tare weight for each of the LSA containers from the total weight measured. The total net mass of sludge product was determined to be 4.9 tons.

3.4.4.2 Process Products Analysis. During the first and last sampling events of the replication run, samples of feed soils, process oversize, sand, and fines were collected for soil particle size distribution analysis. Particle size analysis of the recycled water was not required. Results of these particle size analysis are summarized in Table 3-23 and shown graphically in Figure 3-13.

For each of the process products, the system separation efficiency has been determined. The separation efficiency is defined as the material of the specific size fractions that should be in process product as a percentage of total material in process product.

For each of the process products, high separation efficiencies were achieved ranging from 97.2% (average) for the sludge fraction, 98.8% (average) for the sand fraction, and 99.8%

(average) for the greater than 2-mm oversize fraction. These high separation efficiencies indicate a highly effective separation for all products generated by the soil washing system.

Using the particle size distribution data and correcting for the amount of gross oversize (fraction > 50 mm), the original soil particle size distribution for the unscreened soils (including material > 50 mm) has been calculated and is shown in Table 3-24.

3.4.4.3 Chemical and Radiological Analysis. Similar to the verification run, samples of the feed material, process oversize, clean sand, fines, and recycled water were collected approximately every 30 minutes during plant operations. A total of 10 sampling events were completed, and the samples were analyzed for metals and total uranium, with the first and last sample from each of the materials analyzed for metals, isotopic uranium, and a gamma scan. The recycled water samples were also analyzed for VOCs and total solids. The results of the analysis of the samples of feed material and the four process streams for metals and radionuclides are summarized in Table 3-25. The results of the recycled water analyses for VOCs and total solids are presented in Table 3-19.

Bulk Analyses of the Feed Material and Process Products. As shown in Table 3-25, all the constituents were present at an average concentration less than 10% of the test performance criteria. Further, the average concentrations/activities for most of the constituents were less than 50% of the average concentrations reported for the verification run.

The average aluminum (3,749 mg/kg), antimony (3.2 mg/kg), beryllium (0.31 mg/kg), iron (18,540 mg/kg), lead (3.0 mg/kg), manganese (242 mg/kg), mercury (0.07 mg/kg), silver (1.3 mg/kg), and zinc (30.6 mg/kg) concentrations in the feed material were below values previously reported as background concentrations. The average concentrations of cadmium (0.71 mg/kg), chromium (12.4 mg/kg), and nickel (12.8 mg/kg) in the feed material fell within two times the highest concentrations previously reported as background. The average feed concentration of copper (79.3 mg/kg) was five times the highest reported background concentrations.

The average uranium concentration (1.2 pCi/g) of the feed was above the reported background of 0.6 pCi/g (WHC 1994). Traces of cesium-137 (0.0467 pCi/g) and cobalt-60 (0.0467 pCi/g) were detected in one of the two feed samples. The average thorium-228 (0.487 pCi/g) and potassium-40 (10.5 pCi/g) were also detected in the feed material at trace activities that are below reported background concentrations (WHC 1994).

The data indicate that, with two exceptions, the constituents detected in the process oversize samples were lower in concentration when compared to the feed material. Beryllium was detected at an average concentration of 0.38 mg/kg in the process oversize and was present at an average concentration of 0.31 mg/kg in the feed material. The average concentration of antimony also increased in the process oversize compared to the feed material (6.4 mg/kg versus 3.2 mg/kg). Of the remaining metals, the difference in average concentrations between the feed material and the process oversize was approximately 50% or less for aluminum, chromium, iron, mercury, manganese, nickel, and zinc. Cadmium, copper, silver, and lead concentrations were reduced by a factor of two to three.

Of the radionuclides monitored, the concentrations/activities of uranium in the process oversize were reduced by a factor of approximately 60% compared to the feed material, while

the activities of cesium-137 and cobalt-60 were reduced to levels below the minimum detectable activities.

The average activities of thorium-228 and potassium-40 were essentially equal to the activities in the feed material (0.469 versus 0.487 and 10.5 versus 10.4 pCi/g, respectively).

The concentrations/activities for the constituents present in the process oversize from the replication run had concentrations very comparable to the process oversize from the verification run.

The data in Table 3-25 show that, except for cadmium and mercury whose concentrations were reduced to levels below the detection limit, the concentrations of each of the metals in the clean sand were greater than the concentration reported in the feed material. For silver, aluminum, chromium, copper, nickel, and lead, the difference in the average concentrations was within one standard deviation of the mean for the feed material. For iron, manganese, and zinc, the increase was 40%, 25%, and 65%, respectively. Beryllium and antimony showed the greatest increases.

The differences in the activities of the various radionuclides between the clean sand and the feed material also were minor. For uranium-235, uranium-238, and thorium-228, the differences were within one standard deviation of the mean activity in the feed. The activity of cesium-137 in the clean sand (0.0448 pCi/g) was similar to the activity detected in the initial sample of the feed material (0.0467 pCi/g). The average activity of cobalt-60 in the feed material was 0.0308 pCi/g while the isotope was not detected in the clean sand at a minimum detectable activity <0.04 pCi/g. The activity of potassium-40 also decreased, from 10.5 pCi/g to 9.3 pCi/g.

Like the process oversize, the clean sand from the replication run was very similar to the clean sand from the verification run. The maximum relative percent difference between the two average concentrations of metals was 24% for chromium with most of the relative percent differences less than 10%. Likewise, the results for uranium-235, cesium-137, thorium-228, and potassium-40 had relative percent differences lower than 25%. However, cobalt-60, which was reported in the verification run, clean sand at 0.0467 pCi/g, was not detected in the clean sand from the replication run and the activity (2.1 pCi/g) of uranium-238 was reduced from the verification run by 33% to 1.4 pCi/g in the replication run clean sand.

As expected, the data for most of the metals and radionuclides in Table 3-25 show an increase in the concentrations in the fines compared to the feed material, process oversize, and clean sand. Consistent with the verification run, only the radionuclides uranium-238, and cobalt-60 were present in the fines activities within 10% of the test performance criteria.

Cadmium was not detected in the samples taken of the fines and, therefore, showed a decreased average concentration compared to the feed material. The average concentrations of antimony, beryllium, iron, and zinc increased while the activities of potassium-40 and thorium-228 also increased. The decreased concentrations in the fines or slight increases are consistent with the fact that these constituents are not known to have been significant components of the wastes managed at the site. As such, the concentrations/activities reported are principally associated with the natural abundance of these materials in the soil/mineral matrix. Therefore, the concentrations/activities were not anticipated to show a substantial increase with decreasing particle size.

The average concentrations of chromium (50.2 mg/kg), nickel (76.4 mg/kg), manganese (951 mg/kg), and aluminum (24,090 mg/kg) showed approximately four- to six-fold increases in average concentration when comparing the fines to the feed material. The remaining metals and radionuclides exhibited concentration factors for the average concentration/activities from the feed material to the fines ranging from 8 for lead to over 22 for cobalt-60. However, of these remaining metals and radionuclides, the concentrations of copper (714 mg/kg), silver (13.2 mg/kg), mercury (1.08 mg/kg), and lead (24.1 mg/kg) and the activity of cesium-137 (0.265 pCi/g) ranged from about 10% to less than 1% of the test performance criteria. Only uranium-238 (14.7 pCi/g) and cobalt-60 (0.699 pCi/g) occurred in the fines fraction at approximately 30% and 70% of the test performance criteria, respectively.

Fraction Analysis of the Feed Material and Process Products. As explained in Section 3.4.3.3, based on knowledge of the waste managed, the low levels of constituents present, and the data collected according to the Test Procedure (ART 1994b), the discussions of system efficiencies and contaminant distribution with particle size will be confined to copper and uranium-238.

During the first and the tenth sampling events of the replication run, an additional aliquot of sample was collected of the feed material, process oversize, and clean sand. The sample aliquots were sent to PNL for particle size analysis. The fractions from the particle size analysis were submitted to the Roy F. Weston Laboratory for analysis of metals and total uranium. Chemical and radiochemical analysis of the fractions generated by particle size analysis of the fines were not required. The results of the analyses are presented in Table 3-26. The results of the copper and total uranium analyses are also shown in Tables 3-27 and 3-28, respectively, and are graphically represented in Figures 3-14 and 3-15.

A comparison between the bulk concentrations of the feed material, process oversize, and clean sand discussed above and the total concentrations of copper and the total activities of uranium as calculated from the analysis of the various particle size fractions provides an indication of the internal consistency of the data. The concentration of copper in the feed material samples as reported by the laboratory was 130 mg/kg and 51.9 mg/kg compared to the calculated concentrations of 90.2 mg/kg and 132 mg/kg. The correlation for the measured and calculated copper concentrations in the clean sand was 97.1 mg/kg and 92.4 mg/kg versus 99 mg/kg and 107 mg/kg. The correlation between the average measured and calculated concentrations of the process oversize (24.8 mg/kg versus 46 and 41 mg/kg) did not give good agreement.

The deviations in the process oversize concentrations are likely a result of the difficulty in obtaining homogeneous samples of the coarse materials which could have significantly different copper content. This evaluation is supported by the good agreement shown for the clean sand, which is a reasonably homogeneous material, and the intermediate agreement shown for the feed material, which was typically less homogeneously mixed than the sand but better mixed than the process oversize.

The uranium activity in the feed material as reported by the laboratory was 1.2 pCi/g and 0.7 pCi/g compared to the calculated concentrations of 1.7 pCi/g and 2.2 pCi/g. The correlation for the measured and calculated uranium in the clean sand was 1.1 pCi/g and 1.2 pCi/g versus 0.7 pCi/g and 1.6 pCi/g. The correlation between the average measured and calculated concentrations of the process oversize was 0.23 pCi/g and 0.27 pCi/g versus 1.0 pCi/g and

0.7 pCi/g. Due to the very low concentrations measured, the differences noted are likely a result of the variability in the individual analyses (as specified in the contract the bulk analyses were conducted using alpha spectrometry while the fraction analyses were completed using gamma spectroscopy) as well as due to variability in the matrices between bulk samples and fractioned samples.

The average efficiencies of the 2-mm wet screen and the hydrocyclone (set to separate particles at 0.075 mm) were 99.8% and 98.8%, respectively. The concentration of copper in the misplaced less than 2-mm material present in the oversize from the wet screen was 206 mg/kg, while the concentrations of copper in the fine fractions (<0.075 mm) of the sand product was 929 mg/kg. Although these concentrations are substantially greater than the bulk concentrations, the misplaced material led to an average 0.9% increase in the copper concentration in the process oversize and to an average increase of 9% in the concentration of copper in the clean sand due to the misplaced fines fractions.

A similar evaluation for uranium indicates that the amount of uranium in the less than 2-mm fraction in the process oversize product was 2.1 pCi/g, and in the fine fraction (<0.075 mm) in the sand product was 19.7 pCi/g. Due to the system efficiencies noted above, these concentrations contributed an average 0.4% increase in the process oversize concentration and to an average increase of 19% in the concentration of uranium in the clean sand due to the misplacement.

Bulk Analysis of the Recycled Water. As shown in Table 3-25, the recycled water quality prior to the start of the replication run contained somewhat higher concentrations of metals and uranium than were present at the end of the verification run. The increase in concentration may have been a result of re-suspension of solids during sludge processing and/or during the water balancing. Alternately, it is possible that additional constituents may have dissolved into the recycled water from the settled sludge. Re-dissolution could be due to addition of makeup water, which would reduce the concentration of flocculent and coagulant in the plant water, or upon standing, the concentrations of flocculent and coagulant in the process water may be reduced via absorption, reaction, or degradation.

During the first half hour of operation, the concentrations of metals present at concentrations greater than the detection limit were reduced substantially. Conversely, the concentration of uranium increased slightly from 73 pCi/L to 92 pCi/L. After that time, the concentrations of metals varied based on the operation of the water treatment system and the level of solids in the solids settling tank. It should be noted that the variations in the concentrations of metals correspond to changes in the concentrations of total solids shown in Table 3-19 with higher concentrations of both metals and total solids present in samples HRRWA-004, HRRWA-005, and HRRWA-007. The concentration of total solids in the recycled water varied from 273 mg/L to 441 mg/L. Conversely, the concentration of uranium decreased slowly during the run, and the concentration changes did not correlate with the presence of total solids in the sample. The lack of correlation of uranium with the total solids concentration may be a reflection of the very low activity of uranium in the feed materials compared to the initial activity in the recycled water.

Similar to the last hours of operation of the verification run, the average concentrations of metals in the recycled water from the replication run exceeded 1,000 µg/L for only aluminum (1,694 µg/L) and iron (1,661 µg/L). The concentrations of the remaining metals were below

100 $\mu\text{g/L}$. Uranium-235 was present in the recycled water at an average activity of 2.8 pCi/L, which is approximately 7% of the average uranium-238 activity (41 pCi/L). Potassium-40, cesium-137, cobalt-60, and thorium-228 were not detected in the recycled water.

As shown in Table 3-19, the initial recycled water quality (HRMWA-001) contained a low concentration of methylene chloride (6 $\mu\text{g/L}$). Traces of methylene chloride (up to 11 $\mu\text{g/L}$) also were reported in 6 of the 10 samples and in the trip blank. Because it was detected in the trip blank, the methylene chloride results in the recycled water samples are considered inconclusive and the presence of methylene chloride in the samples cannot be confirmed. However, it should be noted that methylene chloride is a common laboratory contaminant, and the concentrations reported are possibly a laboratory artifact or represent container contamination. Chloroform was also detected in one sample (HRRWA-001) at 0.9 $\mu\text{g/L}$. Chloroform would be expected to be present in a chlorinated potable water supply that was used as makeup water to replenish the recycled water holding tank. The data indicate that a buildup of VOCs in the recycled water did not occur during the replication run.

3.4.4.4 Contaminant Removal, Mass Balance, and Volume Reduction.

Contaminant Removal. Using the mass balance on a dry-weight basis shown in Table 3-22 and the average activity of uranium-238 and cobalt-60 in the feed material and fines shown in Table 3-25, a percent removal of these two constituents was calculated. The process was calculated to remove over 100% of the cobalt-60 and 70% of the uranium-238.

The greater than 100% removal efficiency calculated for cobalt-60 is biased high. The removal efficiency calculation may be biased due to the following two factors: only two analyses were conducted on cobalt-60 and, therefore, the average activity measured for the two feed samples may not be representative of the activity of all the feed material processed; and the low levels of cobalt-60 present in the feed are subject to significant laboratory counting error. Because cobalt-60 was not detected in the process oversize or clean sand, the results of these analyses can be used to estimate an upper limit on the activity of cobalt-60 that was not removed. Using one-half the minimum detectable activity as an estimate of the activity of cobalt-60 in the clean sand and process oversize, 37% of the cobalt-60 may have been retained in these products. This lower bound on the estimate of the cobalt-60 removal efficiency is 63%. Therefore, the true removal of cobalt-60 is likely greater than 63% but less than 100%. In addition, removal efficiencies for copper and cesium-137, which also are associated with the waste managed at the site, were calculated. The process removed 53% of the cesium-137 and 51% of the copper.

As indicated in Table 3-27, the mass of copper in the samples of the feed material subjected to particle size analysis is distributed approximately 30% in the fraction greater than 2 m (process oversize), 30% in the fraction between 0.075 and 2 mm (clean sand), and 40% in the fines less than 0.075 mm. As shown in Table 3-28, for uranium-238, the average mass distribution of the feed material was calculated to be 27% for the fraction greater than 2 mm, 23% for the fraction between 2 mm and 0.075 mm, and 50% for the fraction less than 0.075 mm. These distributions compare with the 70% removal calculated for uranium and the 51% removal calculated for copper in the bulk fines, which was discussed above.

Similar to the verification run, the copper and uranium-238 distribution data for the feed material, shown in Figures 3-14 and 3-15, indicate that a separation point in the range of

0.425 mm and 0.045 mm would result in removal of a significant mass of both constituents while obtaining a 90% or better mass reduction. However, like the verification run, inclusion of the sand fractions above 0.045 mm only increases the removal of copper and uranium by approximately 25% while increasing the mass of waste (fines) by a factor of two.

Mass Balance. The process product mass balance for the replication run is presented in Table 3-22 and Figure 3-16. As shown in Table 3-22, the mass recovery of the products on a dry-weight basis for the total run was 102.3%, indicating a good closure of the mass balance. Based on the original soil particle size distribution, the fractional distribution of gross oversize fraction (> 50 mm), oversize fraction (2.0 - 50 mm), sand fraction (0.075 - 2.0 mm), and fines fraction (<0.075 mm) has been calculated and compared to the fractional distribution of the field test. The results of the calculated fraction distribution and the fraction distribution measured in the field for the run are summarized in Table 3-29, and a graphical comparison is shown in Figure 3-17. Between the calculated and measured fraction distribution for the replication run, some difference exists. This can be explained by an apparently biased feed sample collected at the final sampling event of the run. The particle size distribution of this sample seems strongly biased towards the sand and fines fraction as compared to all other particle size distribution analysis of data available on the same feed material. Therefore, the fraction distribution of the field test is considered to be more accurate and gives a better representation of the actual situation. Based on results of the field test, the original soils used for the replication run contained approximately 27% of gross oversize (> 50 mm), 55% of oversize (2.0 - 50 mm), 14% sand (0.075 - 2.0 mm), and 4% fines (<0.075 mm) on a dry-weight basis.

Volume Reduction. The volume reduction by weight for the replication run has been calculated based on the total mass balance (including the fraction > 50 mm) data as summarized in Table 3-30. The volume reduction by weight has been calculated using the following formula:

$$\text{Volume Reduction by Weight (\%)} = \frac{(A-D-E_{sw}) \times 100}{A}$$

- A - Total tons processed (including > 50-mm material)
- D - Total tons of contaminated material
- E_{sw} - Total tons of secondary waste.

Total Tons Processed (A). The total tons processed refers to original soil including material greater than 50 mm. Since the soils were prescreened at 50 mm prior to processing, the fraction of greater than 50-mm material corresponding with the amount of minus 50-mm plant feed needs to be included for the determination of the volume reduction by weight. The plus 50-mm fraction corresponding with the amount of minus 50-mm plant feed was calculated using the ratio of plus 50-mm fraction versus minus 50-mm fraction as determined in the prescreening. The sum of the minus 50-mm plant feed processed through the soil washing system and calculated fraction of plus 50-mm fraction constitutes the total tons processed of original soil for this run.

Total Tons of Contaminated Material (D). For the soil washing process the only contaminated fraction generated was the sludge cake product. The total mass of the sludge product for this run as produced and weighed in the field has been used for calculation of the volume reduction by weight.

Secondary Waste (Esw). The total amount of secondary waste as calculated in Section 3.4.3.4 indicated that the total amount of secondary waste was insignificant (<0.01 tons) for each run. Therefore, the amount of secondary waste has been neglected for the mass balance evaluation.

Based on this analysis, and using the data as summarized in Table 3-30, the volume reduction by weight for the replication run was determined to be:

$$\text{Volume Reduction by Weight (Replication Run)} = 93.2 \%$$

3.4.5 Uranium Carbonate Run

3.4.5.1 Description. The purpose of the uranium carbonate run was to determine the feasibility of physical soil separation and degree of volume reduction that can be achieved for soils containing visually identifiable green uranium carbonate material.

The uranium carbonate run was conducted on April 12, 1994. As feed material for the uranium carbonate run, prescreened soils (containing visually identifiable "green" material) were used. Attritioning was included in the system for this run.

The run was conducted in four processing cycles. In the first processing cycle, feed material was introduced into the pilot plant. The purpose of this first cycle, referred to as the first attritioning cycle, was to screen out the greater than 2-mm process oversize fraction, separate the fines, and attrition the sand fraction. The density of the pulp, which includes the sand with some fines and recycled water from the underflow from the hydrocyclone, is a major controlling factor in the efficiency of the attrition scrubber. The pulp density to the attritioning unit was measured to be 56% solids. After this first attritioning cycle, it was noticed that the sand product still contained a significant amount of green-colored particles that had not been broken down in the attritioning treatment. When measured with a Geiger-Müller (GM) Counter, 2,500 to 4,000 dpm were measured, indicating the presence of a substantial amount of particulate uranium carbonate material in the sand fraction.

Based on these observations, it was decided to reprocess the sand through the attrition scrubber and improve the attritioning effectiveness. By controlling the feed rate of the previously separated sand fraction directly to the pilot plant, an increase in the total residence time and an increase in the pulp feed density within the attrition scrubber was achieved. The pulp feed density in the attritioner cell was measured to be 65% solids during this second attritioning cycle. After this second cycle, it was noticed that the amount of green material present in the sand fraction was substantially reduced, but still particulate green material could be visually identified throughout the treated sand pile. GM readings performed on the sand fraction after the second attritioning cycle confirmed the presence of radioactive material in the treated sand.

Since a significant reduction in the amount of visually identifiable green material and reduction in radioactivity was experienced after the second attritioning cycle, it was decided to make a third pass through the system to further improve the sand product quality through increased efficiency of the attritioning treatment. The pulp feed density to the attritioning unit was increased to 67% solids for this cycle. After the third attritioning cycle, it was noticed that

the bulk of the green material was removed, but still some particulate green material could be identified. GM readings were around 1,000 dpm above background, indicating that some traces of radioactive material remained.

A fourth and final pass through the soil washing system was made with the objective of separating the secondary fines, generated in the attritioning cycles, from the sand product. This fourth processing cycle is referred to as the washing cycle. Although the main purpose of the washing cycle was to separate secondary fines, the sand fraction was also passed through the attritioning unit. The pulp feed density to the attritioning unit for this cycle was 70% solids. After the washing cycle, residual radioactivity was not detected with the GM meter. Upon detailed inspection of the sand fraction, some occasional particles of green material could still be visually identified. At this point it was decided to confirm compliance with the test performance criteria by field XRF.

For the uranium carbonate run, a total of 43.1 tons of less than 50-mm soil material was processed during a total of 2 h and 42 minutes of processing time for the first attritioning cycle. The average feed rate during the test was 16.0 tons/h. As process water for the uranium carbonate run, the process water retained in the system after completion of the replication run was used.

The retention time in the attritioning unit (20 ft³ effective volume) for the washing cycle was calculated to be approximately 4.5 minutes based on a total processing time of 43 minutes, the total mass of 8.8 tons of sand, a feed density to the attritioning unit of 70% solids, and a feed rate to the attritioning unit of 7.6 m³/h. The retention times for the other three cycles cannot be directly calculated since the mass of sand produced was not monitored between attritioning cycles. Because the plant flows for the other three runs were balanced and the hydrocyclone pressure was controlled, the retention times for the other cycles are not expected to have differed substantially.

Field Weighing/Mass Determination. For weighing of the process products, the same weighing procedures were used as were used for the verification and replication runs. A summary of field weighing results for the uranium carbonate run is presented in Table 3-31. The methods of mass determination for each of the products is briefly described in the following.

Weighing of Plant Feed. Each bucket load of material fed to the soil washing system was weighed prior to introduction into the feed hopper. The total net mass of less than 50-mm feed material was 43.1 tons.

Weighing of Oversize Product. After completion of the processing, the oversize product was collected by the loader and weighed. Although a good effort was made to collect all of the product, not all material could be collected by the loader. The total estimated mass was 29.6 tons.

Weighing of Sand Product. After completion of the processing, the sand product was collected by the loader and weighed. Although a good effort was made to collect all of the product, not all material could be collected by the loader. The total estimated mass was 10.0 tons.

Weighing of Sludge Product. After completion of filter press operations, the sludge product was collected in two LSA containers. These containers were weighed after completion of the run by use of a mobile crane equipped with a load scale. The net weight was determined by subtracting the known tare weight for each of the LSA containers from the total weight measured. The total mass of sludge product was determined to be 4.5 tons.

3.4.5.2 Process Products Analysis. During the first and last sampling events during the first attritioning cycle of the uranium carbonate run, samples of feed soils, process oversize, and fines were collected for soil particle size distribution analysis. In addition, samples of the final clean sand product, collected at the first and last sampling events of the final washing cycle were also submitted for particle size distribution analysis. Particle size distribution analyses of the recycled water were not required. Results of these particle size analyses are summarized in Table 3-32 and are shown graphically for the feed samples in Figure 3-18.

For each of the process products, the system separation efficiency has been determined. The separation efficiency is defined as the material of the specific size fractions that should be in process product as a percentage of total material in process product.

For each of the process products, high separation efficiencies were achieved of 97.8% for the oversize fraction (2.0 to 50 mm), 99.0% for the sand fraction, and 92.8% for the sludge fraction. These high separation efficiencies indicate a highly effective separation for all products generated by the soil washing system.

Using the particle size distribution data and correcting for the amount of gross oversize (fraction > 50 mm), the original soil particle size distribution for the unscreened soils (including material > 50 mm) has been calculated and is shown in Table 3-33.

3.4.5.3 Chemical and Radiological Analysis. In accordance with the Test Procedure (ART 1994b), the uranium carbonate run was scheduled to process the feed soils in two steps. In the first step, the attritioning cycle, the feed soil was separated into the process products as before. Because the sand product after the first step required additional processing, the sand product was not sampled during the first attritioning cycle. Samples of the feed material, process oversize, fines, and recycled water were collected approximately every 30 minutes during plant operations in this first step. A total of five sampling events were completed, and the samples were analyzed for metals and total uranium, with the first and last sample from each of the materials analyzed for metals, isotopic uranium, and a gamma scan. The recycled water samples were also analyzed for VOCs and total solids. The results of the analysis of the samples of feed material and the three process streams (excluding the sand) for metals and radionuclides are summarized in Table 3-34. The results of the recycled water analyses for VOCs and total solids are presented in Table 3-19.

As discussed above, it was necessary to attrition the sand product through several cycles prior to beginning the second step of the process, the washing cycle. During the additional attritioning cycles, two additional samples of recycled water were collected. During the washing cycle, one additional sample of recycled water and one additional sample of fines as well as four samples of clean sand were collected. The samples were analyzed for metals and total uranium, with the first and last sample of the clean sand and the single sample of recycled water analyzed for metals, isotopic uranium, and a gamma scan. The recycled water sample was also analyzed for VOCs and total solids. The results of the metals and radiochemical analyses of these samples

also are summarized in Table 3-34. The results of the recycled water analyses for VOCs and total solids are presented in Table 3-19.

Bulk Analyses of the Feed Material. Unlike the previous two runs, the uranium carbonate run processed soils containing substantial quantities of waste material. As such, the feed material contained uranium (397 mg/kg or 132 pCi/g as uranium-238) above the test performance criteria. With the exception of beryllium, antimony, iron, manganese, and potassium-40, the constituent concentrations/activities in the feed material for the uranium carbonate run exceeded the concentrations/activities encountered in the previous runs. Further, except for beryllium, antimony, and manganese, the average concentrations reported in the feed material samples were greater than the highest background concentrations presented in Table 3-4.

The average aluminum (10,834 mg/kg), cadmium (1.16 mg/kg), iron (31,900 mg/kg), and zinc (83.4 mg/kg) concentrations in the feed material were less than twice highest reported background concentrations shown in Table 3-4. The average concentration of lead (19.9 mg/kg) was approximately four times the highest reported background concentrations, whereas the average chromium (177 mg/kg), silver (23.8 mg/kg), mercury (2.2 mg/kg), and nickel (223 mg/kg) concentrations were between 15 and 30 times the highest background concentrations presented in Table 3-4. Copper was present at an average concentration of 2,768 mg/kg, which is over 200 times the previously reported background value.

The uranium-235 activity (4.5 pCi/g) of the feed was 10 to 20 times higher than the concentration detected in the previous runs. As before, traces of cesium-137 (0.127 pCi/g) and cobalt-60 (0.0803 pCi/g) were detected in the feed samples. These activities are slightly above the activities reported for the two previous runs (0.0467 and 0.0308 pCi/g for cobalt-60 and 0.0418 and 0.0284 pCi/g for cesium-137). Thorium-228 (1.91 pCi/g) was also detected above the activity reported in the feed material from the previous two runs. Only uranium-238 was present in the feed at a concentration/activity above the test performance criteria.

Bulk Analysis of Process Oversize. None of the constituents detected in the process oversize samples had concentrations/activities that exceeded the test performance criteria. The constituent closest to the test performance criteria was uranium-238 with an activity of 5.5 pCi/g compared to 50 pCi/g. The remaining constituents had average concentrations/activities that were less than 6% of the test performance criteria.

Based on the constituents detected in the feed material, only potassium-40 was present in the process oversize samples at a higher average activity (10.4 to 13.8 pCi/g). Of the remaining constituents, all the reported concentrations/activities were lower in the process oversize when compared to the feed material. The greatest reduction in concentration/activity occurred for uranium (from 132 pCi/g to 5.5 pCi/g, a 24-fold decrease, and for copper (2,768 to 199 mg/kg) and mercury (2.2 mg/kg to 0.17 mg/kg), 14-fold and 13-fold decreases, respectively. For chromium, lead, and silver, the reduction in concentration ranged from approximately a factor of 5 to 10, while for the remaining constituents, aluminum, beryllium, iron, antimony, zinc, cesium-137, and thorium-228, the drop in concentration was a factor of 5 or less. The average concentration of cadmium and the average activity of cobalt-60 were reduced below detectable levels in the process oversize.

The average concentrations/activities for beryllium, cadmium, iron, manganese, antimony, zinc, cobalt-60, and potassium-40 in the process oversize from the uranium carbonate run were consistent with the concentrations/activities of these constituents present in the process oversize from the verification and replication runs. The remaining metals and radionuclides had higher concentrations/activities in the process oversize from the uranium carbonate run when compared to the other two runs. The process oversize fraction did not contain any constituents above the test performance criteria.

Bulk Analysis of the Sand Product. The data in Table 3-34 show that the clean sand product met the test performance criteria for all constituents monitored. Like the process oversize, the constituent that was present closest to the standard was uranium-238 at 28.5 pCi/g compared to the test performance criteria of 50 pCi/g. None of the average concentrations/activities of the remaining constituents were greater than approximately 10% of the test performance criteria.

Except for cesium-137, which increased from 0.127 pCi/g to 0.265 pCi/g, and thorium-228, which increased from 1.91 pCi/g to 2.59 pCi/g, the average concentrations/activities of the constituents detected in the feed material were reduced in the clean sand product. The reductions in concentration/activity varied from approximately 15% for potassium to a factor of seven for mercury. For copper and uranium, the reduction in the average concentrations/activities between the feed material and clean sand product were by factors of 2.3 and 4.6, respectively.

Of the constituents monitored, only potassium-40 had a significantly lower average concentration/activity in the clean sand compared to the process oversize. Iron, manganese, antimony, and cobalt-60 had average concentrations/activities in the clean sand that were close to the average concentrations/activities reported for the process oversize. The remaining constituents all showed higher average concentrations/activities in the sand product than in the process oversize. The increase in concentrations/activities varied from as little as 30% for chromium up to a factor of 6 for copper. The clean sand fraction did not contain any constituent above the test performance criteria.

Bulk Analysis of the Fines. As expected, the data for most of the metals and radionuclides in Table 3-34 show an increase in the concentrations in the fines compared to the feed material, process oversize, and clean sand. However, only the average concentrations/activities of uranium-235 (58 pCi/g), uranium-238 (1,659 pCi/g), and copper (21,960 mg/kg) exceeded the test performance criteria. The average concentration/activity of cobalt-60 (0.93 pCi/g versus 1.0 pCi/g) and chromium (1,213 mg/kg versus 1,600 mg/kg) were near the test performance criteria.

The average concentrations of beryllium and iron showed slight decreases from the feed material to the fines, while the activity of potassium-40 remained essentially unchanged. The average concentrations of manganese and antimony increased by factors of 1.1 and 3, while the majority of the metals, silver, aluminum, cadmium, chromium, mercury, nickel, lead, and zinc showed increases in the average concentrations by factors between 4.5 and 10 when comparing the feed material to the fines. Of the radionuclides, cesium-137 showed an average increase in activity of a factor of five, while the remaining radionuclides, uranium-235, cobalt-60, and thorium-228, had increases in activity between a factor of 10 and 15. Uranium-238 was

concentrated from the feed material to the fines by a factor of 12.5 while copper was concentrated by a factor of 8.

Fraction Analysis of the Feed Material and Process Products. As explained in Section 3.4.3.3, based on knowledge of the waste managed, the low levels of constituents present, and the data collected according to the Test Procedure (ART 1994b), the discussions of system efficiencies and contaminant distribution with particle size will be confined to copper and uranium-238.

During the initial and the final sampling events of the first attritioning cycle, an additional aliquot of sample was collected of the feed material and process oversize. Likewise, during the initial and final sampling event of the washing cycle, an additional aliquot of clean sand product was collected. The samples were sent to PNL for particle size analysis. The fractions from the particle size analysis were submitted to the Roy F. Weston Laboratory for analysis of metals and total uranium. Chemical and radiochemical analyses of the fractions generated by particle size analysis of the fines were not required. The results of the analyses of the particle size fractions from the feed material, process oversize, and clean sand are presented in Table 3-35. The results of the copper and uranium analyses are also shown in Tables 3-36 and 3-37, respectively, and are also presented graphically in Figures 3-19 and 3-20.

A comparison between the bulk concentrations of the feed material, process oversize, and clean sand discussed above, and the total concentrations of copper and the total activities of uranium as calculated from the analysis of the various particle size fractions provides an indication of the internal consistency of the data. The concentration of copper in the corresponding feed material samples as reported by the laboratory was 1,680 mg/kg and 1,570 mg/kg compared to the calculated concentrations of 3,838 mg/kg and 2,626 mg/kg. The correlation for the measured and calculated copper concentrations in the clean sand was 1,140 mg/kg and 1,130 mg/kg versus 1,245 mg/kg and 1,016 mg/kg. The correlation between the average measured and calculated concentrations of the process oversize was 217 mg/kg and 98.7 mg/kg versus 376 and 188 mg/kg. The deviations in the feed and process oversize evaluation are likely a result of the difficulty in obtaining homogeneous samples of the coarse materials which could have significantly different copper content.

The activity of uranium-238 in the corresponding feed material samples as reported by the laboratory was 90 pCi/g and 81 pCi/g compared to the calculated concentrations of 197 pCi/g and 158 pCi/g. The correlation for the average measured and calculated uranium-238 activity in the clean sand was 27 pCi/g and 26 pCi/g versus 39 pCi/g and 34 pCi/g. The correlation between the measured and calculated activities of the process oversize was 8.8 pCi/g and 2.7 pCi/g versus 27 pCi/g and 12 pCi/g. As discussed in earlier sections, the heterogeneity of the samples and the differences in the methods of analysis for uranium is suspected to have had a significant effect on the reported concentrations in the feed material and process oversize samples.

The average efficiencies of the 2-mm wet vibrating screen varied from 96.4% to greater than 99%. The concentration of copper in the two fractions less than 2 mm present in the process oversize produced were 3,370 mg/kg and 23,800 mg/kg. However, due to small amounts of misplaced material in the oversize product, the copper in the two misplaced fractions contributed to an average 50% increase in the process oversize concentration. The average efficiency of the hydrocyclone (set to separate particles at 0.075 mm) was 99%, while the

concentrations of copper in the fine fraction less than 0.075 mm was 13,200 mg/kg. For the clean sand, the incomplete separation of the material less than 0.075 mm led to an average increase of 12% in the concentration of copper in the clean sand.

A similar evaluation for uranium indicates that the amount of uranium in the two fractions less than 2 mm from the 2-mm screen were 287 pCi/g and 2,300 pCi/g and in the fine fraction (<0.075 mm) from the hydrocyclone was 1,433 pCi/g. Due to the system efficiencies noted above, the concentrations contributed an average 68.2% increase in the process oversize concentration as a result of incomplete separation of the less than 2-mm material from the process oversize and to an average increase of 41% in the concentration of uranium in the clean sand due to the incomplete separation of the fines.

Two points should be noted concerning this evaluation. First, during the initial operation period of the first attritioning cycle, the 2-mm screen overloaded with material leading to a lower efficiency than obtained during the previous runs. This led to incomplete separation of visible uranium carbonate sludge from the process oversize. Therefore, the results of the first particle size analysis are not representative of the complete run. Secondly, the calculated concentration of uranium and copper in the process oversize differs substantially from the average measured values. This difference is principally a result of the high calculated concentrations of copper and uranium from the first particle size analysis. Therefore, a more reasonable estimate of the impact of incomplete separation of the process oversize is a 50% increase for the uranium concentration and a 35% increase in the copper concentration as indicated by the calculations for the final sampling event shown in Table 3-37.

Second, the use of the attritioning mill required that the underflow from the hydrocyclone be plumbed to the attritioning mill. Because of the difficulty in making this connection, during the washing cycle, the attritioning mill could not be disconnected and the clean sand product was sent through the attritioning mill prior to sample collection. Therefore, some percentage of the fines noted in the particle size analysis represents secondary fines generated by attrition scrubbing during the washing cycle. As such, the percentages reported for evaluation of incomplete separation for both copper and uranium represent a high estimate as compared to high-performance full-scale processing, which would employ additional hydrocyclones after attritioning to improve separation efficiency and reduce the amount of misplaced material (fines in the sand fraction).

Bulk Analysis of the Recycled Water. As shown in Table 3-34, similar to the replication run, recycled water quality prior to the start of the uranium carbonate run contained somewhat higher concentrations of metals and uranium than were present at the end of the previous run. As discussed earlier, the increase may have been a result of re-suspension of solids or dissolution of metals and uranium from the fines in the solids settling tank due to changes in the concentration of coagulant and flocculent.

During the first half hour of operation and through the fifth sampling event, the concentrations of most of the constituents increased. Antimony, cadmium, manganese, iron, lead, and zinc were exceptions to this pattern. Antimony and cadmium were not detected in any of the samples of recycled water collected during the uranium carbonate run. For manganese, iron, lead, and zinc the concentrations decreased during the first hour to hour and one-half of operation and then increased. For the constituents aluminum, chromium, copper, manganese, nickel, lead, and zinc the highest concentrations were noted during the fifth sampling event

which was the last sampling event where feed material was added to the plant. When the data are compared to the total solids results presented in Table 3-19, it is apparent that the variations in the concentrations of metals correspond to changes in the concentrations of total solids with the highest concentrations of total solids reported during the fifth sampling event. For silver, uranium, beryllium, iron, and mercury, the constituent concentrations peaked or plateaued during the additional attritioning cycles.

Unlike the verification and replication runs, the average concentrations of several constituents including aluminum (4,417 $\mu\text{g/L}$), copper (1,556 $\mu\text{g/L}$), iron (754 $\mu\text{g/L}$), and uranium (2,141 $\mu\text{g/L}$) had average concentrations in the recycled water near or above 1,000 $\mu\text{g/L}$. The concentrations of the remaining metals were near or below 100 $\mu\text{g/L}$. Uranium-235 was present in the recycled water at an average activity of 33 pCi/L, which is approximately 5% of the average uranium-238 activity (714 pCi/L). Potassium-40, cesium-137, cobalt-60, and thorium-228 did not have average activities above minimum detectable activity for these nuclides in the recycled water.

As shown in Table 3-19, the initial recycled water quality (HGMWA-001) contained a low concentration of methylene chloride (6 $\mu\text{g/L}$). Traces of methylene chloride (up to 8 $\mu\text{g/L}$) also were reported in all eight of the samples and in the field, trip, and laboratory blanks. Because it was detected in the associated blanks, the methylene chloride results in the recycled water samples are considered inconclusive, and the presence of methylene chloride in the samples cannot be confirmed. However, it should be noted that methylene chloride is a common laboratory contaminant, and the concentrations reported are likely a laboratory artifact or represent container contamination. No other VOCs were detected in the samples. The data indicate that buildup of VOCs in the recycled water did not occur during the uranium carbonate run.

3.4.5.4 Contaminant Removal, Mass Balance, and Volume Reduction.

Contaminant Removal. Using the mass balance on a dry-weight basis shown in Table 3-31 and the average concentration/activity of uranium-238 and copper in the feed material and fines shown in Table 3-34, a percent removal of these two constituents was calculated. The process was calculated to remove 40% of the copper and 64% of the uranium. However, the calculated percentage of the copper remaining in the clean soil (sand and oversize) constitutes only 15% of the total copper and only 8% of the uranium. By subtracting the contribution of the clean products from the feed material and dividing by the total feed concentration, removal efficiencies of 85% and 92%, respectively, were calculated. The true value for the removal efficiency likely falls between 40% and 85% for copper and 63% and 92% for uranium-238. The difference in the values has two possible sources of error, the laboratory analysis of the process products or the field weights.

There is a possibility that the laboratory data for the fines are biased significantly low for copper and slightly low for uranium. In the inductively coupled plasma analysis of copper (as well as several other metals), the presence of salts especially those of aluminum and iron can have significant impacts on the linearity of the analysis. As noted during the data validation, the laboratory did experience significant increases in reported concentrations when the samples were diluted to verify matrix interferences (serial dilution). The fines from the uranium carbonate run contained high concentrations of many metals, especially aluminum. Because of the five- to six-fold increase in concentration of aluminum from the feed material to the fines, any matrix effect

would be much more pronounced in the analysis of the fines. Conversely, the concentration of aluminum in the oversize and clean sand was less than in the feed leading to less of an interference. Consequently, the concentration of copper in the fines could be substantially greater than reported leading to a much higher removal efficiency than calculated using the data for the fines.

For uranium, there are two noted sources of laboratory error. As discussed in Chapter 4.0, the results of the alpha isotopic analysis of uranium at times differed from the results of total uranium as measured by a gamma scan. Although a review of the raw data for the feed material did not indicate a significant difference in activity, the data for the fines indicated that the two alpha isotopic results may be biased low by 30% to 60%. Using the gamma spectroscopy data to calculate a revised uranium result for samples HGADSL-001 and HGADSL-005 increases the average fines concentration from 1,659 pCi/g to 1,967 pCi/g, which increases the estimated removal efficiency from 63% to 74%. Furthermore, gamma spectroscopy is somewhat affected by differences in the sample matrix that change the gamma-ray absorption and scattering properties of the sample. The spectral properties of the sample with respect to gamma rays are impacted by the concentration of metals in the sample, particularly to changes in the average atomic weight of the metals. As the average atomic weight of the sample increases, additional absorption and scattering of the emitted gamma rays occurs resulting in lower counting efficiencies and results that tend to be biased low. The significant increase in metals, particularly copper and uranium, in the fines compared to the feed samples may have resulted in slightly lower efficiencies and may have biased the fines results low compared to the feed results. Unfortunately, the existing data are insufficient to estimate the magnitude of this effect.

As indicated in Tables 3-36 and 3-37, the mass of copper and uranium in the samples of the feed material subjected to particle size analysis is distributed approximately 10% in the fraction greater than 2 mm (process oversize), 40% in the fraction between 0.075 and 2 mm (clean sand), and 50% in the fines less than 0.075 mm. The 50% mass distribution of copper and uranium in the two finest fraction of feed material provides an estimate of the removal that would be obtained based on separation only without attritioning. To estimate the effects of attritioning, it is necessary to calculate the bulk concentration of the sand fraction before and after attritioning. This is shown in Table 3-38 and illustrated graphically in Figure 3-21.

The calculated bulk concentration of copper before attritioning is determined by the following process. First, the load of copper in milligrams per kilogram of feed is calculated by multiplying the percent distribution in the feed for a particular size fraction by the concentration of copper in that fraction. The calculated copper contribution to the sand product is determined by summing the copper load of the four particle size fractions that make up the sand product. As shown in Table 3-38, the calculated bulk concentration of copper before attritioning was 1,377 mg/kg for the initial sample and 1,068 mg/kg for the second sample.

To calculate the bulk concentration of copper after attritioning, the process is repeated with the following substitution. The concentration of copper in the particle size fractions of the attritioned sand (taken from Table 3-35) is multiplied by the percent distribution of the particle sizes in the feed sample. As shown in Table 3-38, the calculated bulk concentration of copper after attritioning was 362 mg/kg and 206 mg/kg copper. Therefore, an average concentration of 938 mg/kg of copper was removed from the sand fraction to the fines fraction.

Based on the calculated bulk concentrations of copper in the feed material (taken from Table 3-36) of 3,838 mg/kg and 2,626 mg/kg, the amount of copper removed from the sand by attritioning constitutes approximately 30% of the average copper load. Through the attritioning treatment, the mass of copper available for removal from the feed to the fines increased from approximately 50% (as discussed above) to approximately 80% of the total copper in the feed. A similar evaluation for uranium yields an average reduction in the concentration of uranium in the sand by 61 pCi/g. This amount of uranium constitutes an average load of 34%. By transferring this mass of uranium from the sand fraction to the fines, the removal efficiency increased from 50% for separation only to over 80% for separation in combination with attrition treatment.

Unlike the previous runs simple particle size separation is not sufficient to generate a sand product that meets the test performance criteria. Only by disposal of all material less than 2 mm would the remaining material (process oversize) meet the test performance criteria and can be considered for return to the site. Because the process oversize constitutes about 70% of the material onsite, the mass reduction without additional treatment (attritioning) of the sand is quite low. Once the need for additional treatment of the sand is recognized, the selection of a separation point should be based on the particle sizes generated by the attritioning mill. Based on the data shown in Table 3-38, the feed material and attritioned sands contain a reasonably low percent of particles in the 0.045-mm to 0.075-mm range constituting an approximate average load of 6.6 pCi/g. Because the concentration of uranium-238 in the clean sand was 21.6 pCi/g less than the test performance criteria, it would have been possible to lower the separation point to near 0.045 mm and thereby minimize the mass of sludge designated for disposal. After attritioning, use of a separation point above 0.045 mm to 0.075 mm would simply increase the mass of sludge requiring disposal while achieving only a minimal increase in the mass of contaminants removed.

Mass Balance. The process product mass balance for the uranium carbonate run is presented in Table 3-31 and Figure 3-22. As shown in Table 3-31, the mass recovery of the products on a dry-weight basis for the total run was 100.6%, indicating a good closure of the mass balance. Based on the original soil particle size distribution, the fractional distribution of gross oversize fraction (> 50 mm), oversize fraction (2.0 - 50 mm), sand fraction (0.075 - 2.0 mm), and fines fraction (< 0.075 mm) have been calculated. The results of the calculated fraction distribution and actual fraction distribution as determined for the run are compared in Table 3-39 and Figure 3-23. Between calculated and measured fraction distribution for the uranium carbonate run, some difference exists. This difference may be caused by one of the two feed samples being slightly biased. In addition, the calculated fraction distribution does not account for the extra fines generated during the attritioning. Therefore, the fraction distribution of the field test is considered to be more accurate and to give a better representation of the actual situation. Based on results of the field test, the original soils used for the replication run contained approximately 17.6% of gross oversize (> 50 mm), 60% of oversize (2.0 - 50 mm), 19% sand (0.075 - 2.0 mm), and 4.1% fines (< 0.075 mm) on a dry-weight basis.

Volume Reduction. The volume reduction by weight for the verification run has been calculated based on the total mass balance (including the fraction greater than 50 mm) data as summarized in Table 3-40. The volume reduction by weight has been calculated using the following formula:

$$\text{Volume Reduction by Weight (\%)} = \frac{(A-D-E_{sw}) \times 100}{A}$$

- A - Total tons processed (including > 50-mm material)
 D - Total tons of contaminated material
 E_{sw} - Total tons of secondary waste.

Total Tons Processed (A). The total tons processed refers to original soil including material greater than 50 mm. Since the soils were prescreened at 50 mm prior to processing, the fraction of greater than 50-mm material corresponding with the amount of minus 50-mm plant feed needs to be included for the determination of the volume reduction by weight. The plus 50-mm fraction corresponding with the amount of minus 50-mm plant feed was calculated using the ratio of plus 50-mm fraction versus minus 50-mm fraction as determined in the prescreening. The sum of the minus 50-mm plant feed processed through the soil washing system and calculated fraction of plus 50-mm fraction constitutes the total tons processed of original soil for this run.

Total Tons of Contaminated Material (D). For the soil washing process, the only contaminated fraction generated was the sludge cake product. The total mass of the sludge product for this run as produced and weighed in the field has been used for calculation of the volume reduction by weight.

Secondary Waste (E_{sw}). The total amount of secondary waste as calculated in Section 3.4.3.4 indicated that the total amount of secondary waste was insignificant, less than 0.01 tons for each run. Therefore, the amount of secondary waste has been neglected for the mass balance evaluation.

Based on this analysis and using the data as summarized in Table 3-40, the volume reduction by weight for the uranium carbonate run was determined to be:

$$\text{Volume Reduction by Weight (Uranium Carbonate Run)} = 91.4 \%$$

3.5 OVERSIZE MATERIAL ATTRITION TEST - URANIUM CARBONATE RUN

During and after performance of the uranium carbonate run, it was noticed that some fine gravel-size green material that had not been broken down in the wet screening process had reported to the oversize fraction (2.0 mm to 50 mm). Although the test performance criteria were achieved for the bulk oversize fraction, an additional attrition test was performed to determine whether the quality of the oversize product could be further improved for full-scale soil washing operations through attritioning of the oversize fraction through pretreatment in an attrition mill prior to the wet screening process.

To simulate the effect of an attrition mill, a portable cement mixer was used to perform the attrition test. Although an attrition mill will be much more efficient with respect to the attritioning action, the cement mixer test was believed to give a good indication of the potential benefits of an additional attritioning treatment step for the oversize fraction.

For the purpose of the test, 67 lb of prescreened soil as used to perform the uranium carbonate run (5-gal bucket) was introduced into the cement mixer and the cement mixer was turned on for 15 minutes. In the cement mixer, tumbling and shearing of the soil and coarse gravel material occurred. After 15 minutes, the cement mixer was stopped and the treated soil was removed from the mixer and wet screened in the field at 2 mm. The greater than 2-mm fraction retained on the 2-mm screen was rinsed with clean water and collected in a plastic bucket for particle size analysis and chemical analysis of the fractions by field XRF.

Results of the contaminant distribution prior to and after the attritioning test for each of the oversize fractions are presented in Table 3-41. Based on a comparison of the contaminant distribution prior to and after attritioning, it appears that additional removal efficiencies in the range of 40% to 50% may be achieved for both copper and uranium for the fraction of approximately 2.0 mm to 12.5 mm. These removal efficiencies should be considered indicative for the potential of additional contaminant removal in the oversize fraction. In a well-designed full-scale soil washing system, higher removal efficiencies will be achieved as compared to this simple test.

Based on the attrition test it seems that the quality of the oversize fraction can be improved through an additional attritioning treatment step. The need for such an additional oversize treatment step should be evaluated based on performance standards established for full-scale soil washing operations. In addition, prior to final detailed design of the soil washing system, consideration should be given to soil and contaminant characteristics of other soils from the 300 Area that have been identified for potential soil washing treatment.

3.6 RESIDUALS MANAGEMENT

Products and residuals generated as a result of the study have been retained in the North Process Pond and will remain there until incorporated into the activities of the full-scale remediation.

3.6.1 Process Products Storage

The clean products, the gross oversize, the process oversize, and the sand were staged near the former excavation area and long ditch along side the eastern berm in the pond. At the conclusion of the pilot study activities, the materials were pushed into the perimeter depression and roughly graded.

The sludge cake generated during the program was stored in B-25 LSA boxes on the south edge of the process pond. Seven LSA boxes were staged in the area containing a total of 18.6 tons of sludge cake. The LSA boxes are lined and closed with the integral cover.

The water generated during the study was not treated and was pumped for storage to the existing fractionation tanks located in the process pond. Approximately 5,000 gal of process water was stored in this manner.

3.6.2 Characteristics of the Soil Washing Sludge

The sludge cake was further evaluated with respect to the provisions of RCRA. Based upon a review of the feasibility study (DOE-RL 1994b) and 40 CFR 261, wastes generated from selected units within the 300-FF-1 Operable Unit may be listed as hazardous by nature of containing a listed hazardous waste. A final determination concerning the disposal of RCRA listed waste into the North Process Pond had not been made at the time of this report. Therefore, the issue of whether the sludge contains a listed waste has not been resolved.

Independent of the listed waste issue, the sludge cake may be a RCRA characteristic hazardous waste by virtue of its reactivity, corrosivity, ignitability, or toxicity. Process knowledge indicates that the sludge cake is not ignitable (it is not a solid, it does not spontaneously ignite, nor is it an oxidizer); it is not corrosive (the pH of the waters in contact with the sludge were between 2.0 and 12.5 SU); nor is the sludge reactive (the sludge was generated from a water slurry and therefore does not react violently with water, it did not generate toxic gases when in contact with water, there was no evidence to indicate the presence of sulfides or cyanides in the sludge and there is no information to indicate that the sludge is an explosive). The toxicity characteristic of the waste was evaluated by further testing.

On April 26, 1994, one sample of the sludge cake from each of the four process runs was collected from the LSA containers and submitted to the Roy F. Weston Laboratory for analysis. The Toxic Characteristic Leaching Procedure (TCLP) was performed on each of the samples for the complete list of 39 TCLP constituents. The results of these analyses are presented in Table 3-42. No organic constituents were detected and, of the four metals that were found, none exceeded the toxic characteristic limit. On the basis of this testing, the sludge cake is not a RCRA characteristic hazardous waste.

3.7 COMPARISON TO PREVIOUS STUDIES

The primary and most contemporaneous document comparable to the ART study is the *300-FF-1 Operable Unit Remedial Investigation Phase II Report: Physical Separation of Soils Treatability Study* (DOE-RL 1994a). DOE-RL (1994a) made several key conclusions that are reviewed and commented on here:

- In DOE-RL (1994a), it was found that the primary risk drivers were uranium-238 and uranium-235.

ART concurs with the finding regarding uranium-238, but because of the reasonable constant relationship in the activities between the two isotopes in the wastes disposed (^{235}U pCi/g/ ^{238}U pCi/g < 10%), the contribution from the uranium-235 isotope to attainment of the test performance criteria for the North Process Pond sediments was not of significant importance.

- DOE-RL (1994a) found that after processing, the significant contribution of the contamination was found in the soil fraction smaller than 0.425 mm. Further, WHC found that using a cut point of 0.425 mm, a 98.6% reduction by weight was observed.

ART's data showed that a cut point of 0.425 mm would produce a reduction on a dry-weight basis of 85% for soils containing the green uranium carbonate material to 92% for soils not containing the green material. The reduction on a wet-weight basis would be substantially lower. ART found that a cut point near or slightly above 0.075 mm was necessary to consistently achieve a 90% reduction by weight.

- DOE-RL (1994a) recommended that careful consideration be given in the Phase III feasibility study to physical separation regarding soils that are near background levels and below test performance levels prior to processing.

ART found during the conduct of the study that a large volume of soils in the North Process Pond were not contaminated to levels above the test performance criteria. Therefore, the volume of soil to be treated will be very dependent on the remediation goals established for the site. Depending on the constituent concentrations established as remediation goals, it may not be necessary to remediate a large volume of the soils in the North Pond as well as the other process units comprising the operable unit. Consequently, a very significant savings can be recognized by a program of "selective excavation." Under this approach, soils excavated would be prescreened using realtime field analytical capabilities to determine which soils need to be treated and which do not. Only the soils exceeding the remediation goals would be forwarded to the physical separation plant, and those already less than the remediation goals would be staged for backfilling as clean material. This concept of selective excavation is included in the Phase III feasibility study (DOE-RL 1994b), and estimates of actual volumes requiring treatment are included.

- DOE-RL (1994a) reported that the soils containing the green material can likely be processed with the addition of an attrition scrubber to the system tested.

ART did add the attritioner to the system and specifically evaluated its use during the uranium carbonate run. The attrition scrubber was effective in reducing the contaminant level in the sand to below the test performance criteria.

- DOE-RL (1994a) suggested that physical separation processes are not recommended for treating concentrated soil fines such as the intact green layer or fly ash.

ART's work indicates that where the green material is intermixed and commingled with natural soils, it is feasible to treat the material and obtain effective separations. Therefore, it is not necessary to exclude soils containing green material from the feed to the full-scale plant. The fly ash was not encountered during the ART study, and therefore no conclusions have been drawn.

- Water treatment tests were reported in DOE-RL (1994a) to be conducted in the spring of 1994.

ART did not conduct any water treatment tests even though it is clear that solubilized "green" constituents in the recycled water will need to be addressed in the use of a full-scale soil washing system in the North Pond area. At the request of WHC, ART did collect samples of the process water for evaluation by WHC. Additional data are available in Serne et al. (1993) and DOE-RL (1994b).

3.8 SUMMARY OF RESULTS AND COMPARISON TO TEST OBJECTIVES

ART completed the processing of soils and residuals on April 15, 1994, and completed the decontamination of the plant on June 3, 1994. A summary of the process runs and products generated by the pilot study is shown in Tables 3-43 and 3-44.

The soils in the North Process Pond are naturally occurring Hanford formation materials with the existence of a uranium carbonate sludge intermixed. The soil is very coarse of approximately 75% oversize, 20% sand, and 5% fines, on a dry-weight basis as shown in Tables 3-45 and 3-46 and Figure 3-24.

During the performance of the field testing, a significant number of samples were collected and analyzed to determine field and separation performance capabilities. Samples were physically separated to determine particle size distributions on specific feeds and products, while chemical and radiological analyses were performed in accordance with the test procedure. Two hundred ten onsite radiological analyses were performed using XRF for the quantitation of total uranium, while 295 samples were prepared, released, and shipped offsite for detailed analysis for metals, isotopic uranium, and other chemical analyses. The Roy F. Weston Laboratory managed the basic chemical and radiological work, while the Data Chem Laboratories provided the quality assurance analysis.

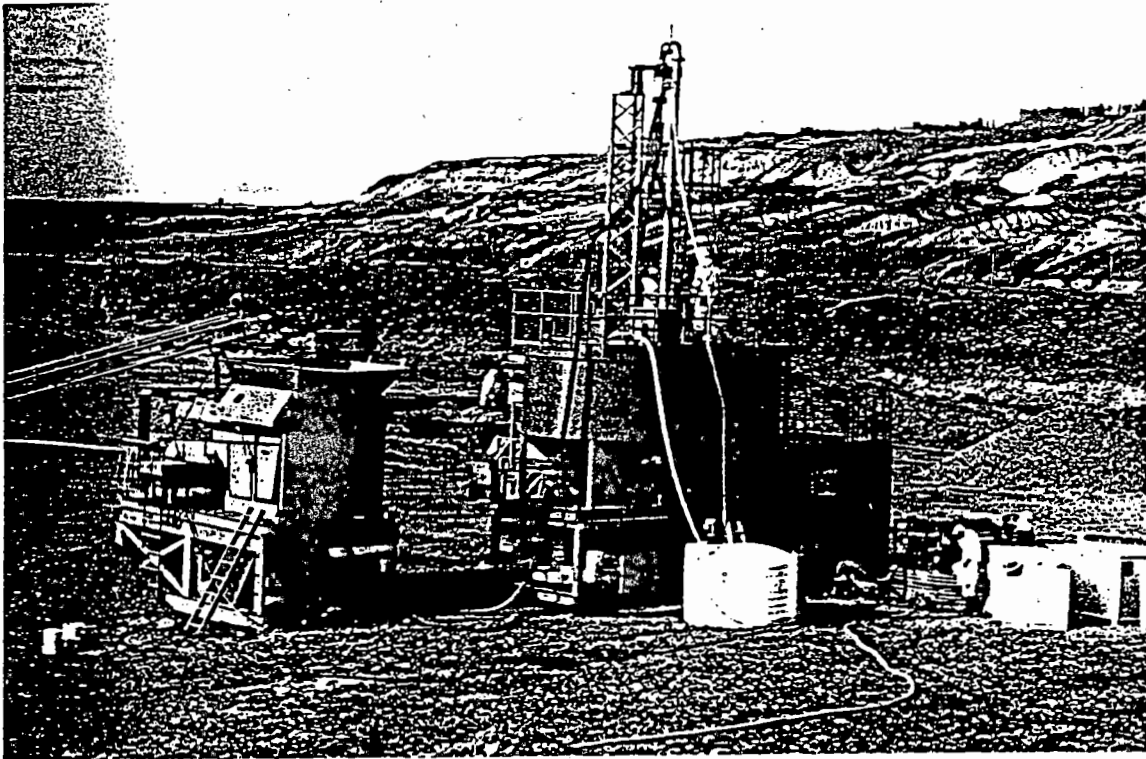
As shown in Table 3-47, the contaminants in the work area consist of heavy metals and the radioactive elements, uranium, thorium, potassium, cobalt, and cesium. The soil not containing the green materials contained concentrations/activities of the monitored constituents that were consistently less than the test performance criteria, while the soils containing the green material contained uranium-238 at an activity substantially above the test performance criteria.

The contaminant and volume reduction exceeded the requirements for the study. For the normal soils (soils not containing the green material), a volume reduction of 93.8% was achieved, while in the processing of the uranium carbonate material, a volume reduction of

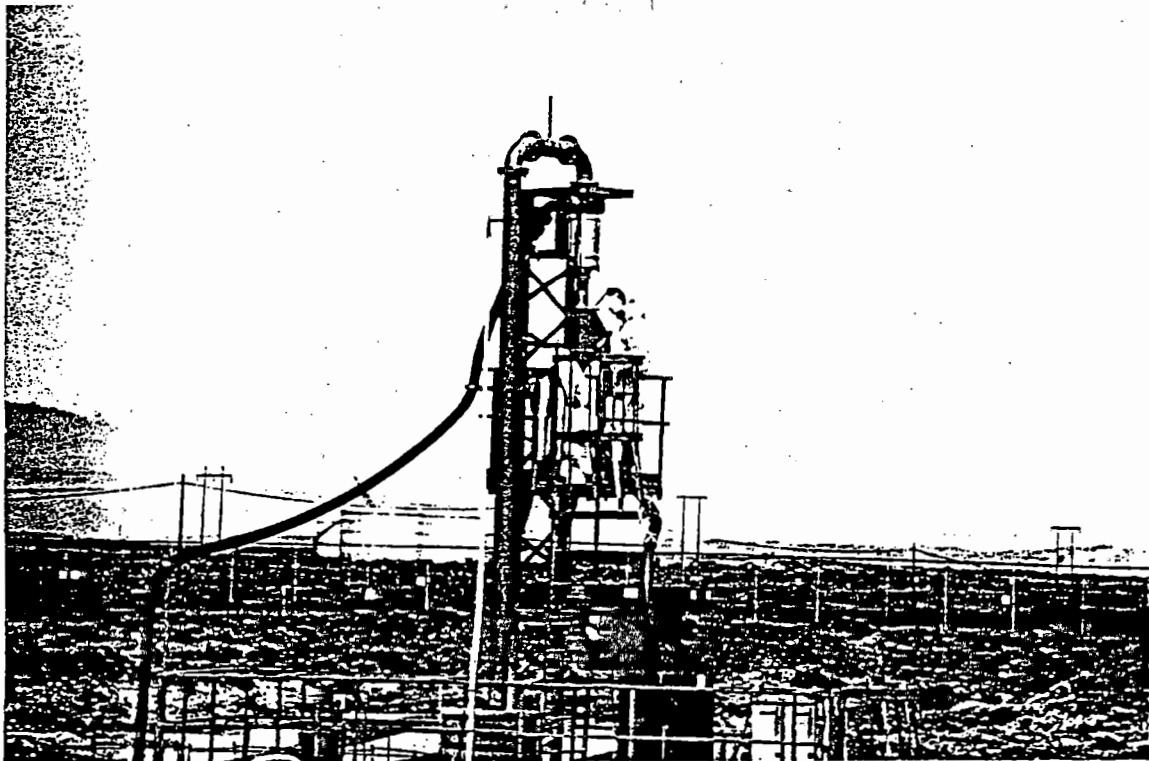
91.4% was obtained. In both cases, the clean products met the contaminant concentration levels as defined in the test performance criteria.



Figure 3-2. Plant Layout.

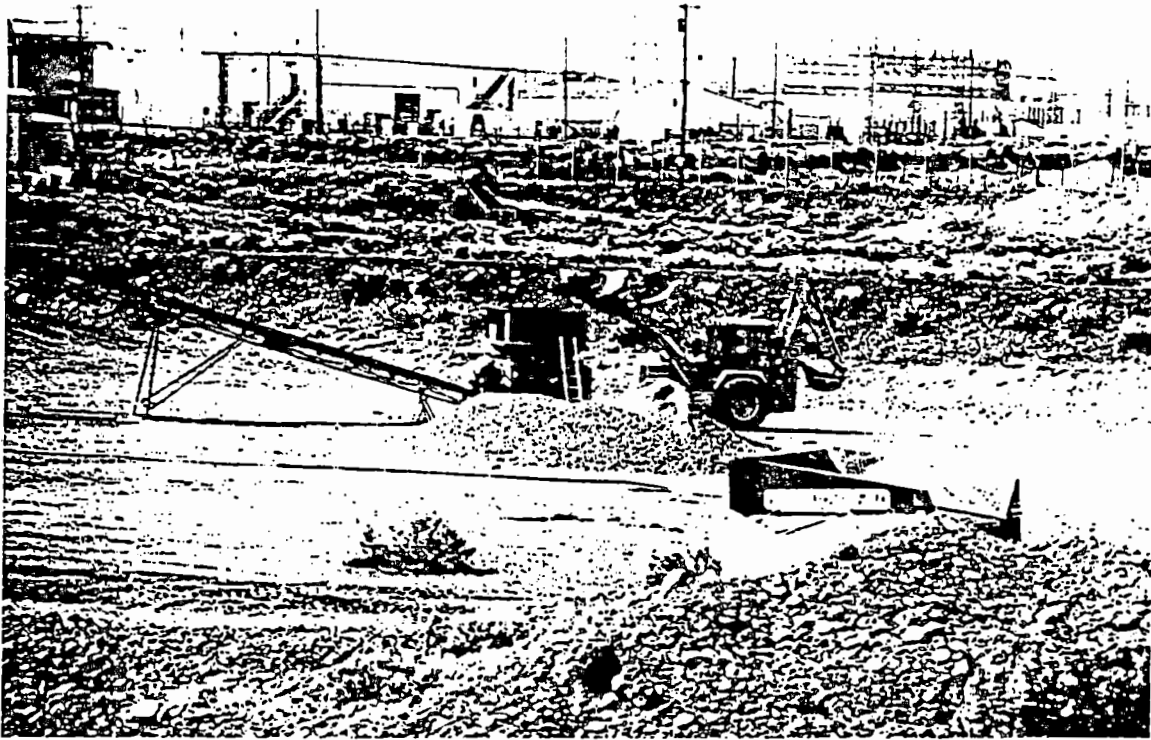


A. ART Pilot Plant.



B. Hydrocyclone and Attritioner Detail.

Figure 3-3. Feeding Operations.

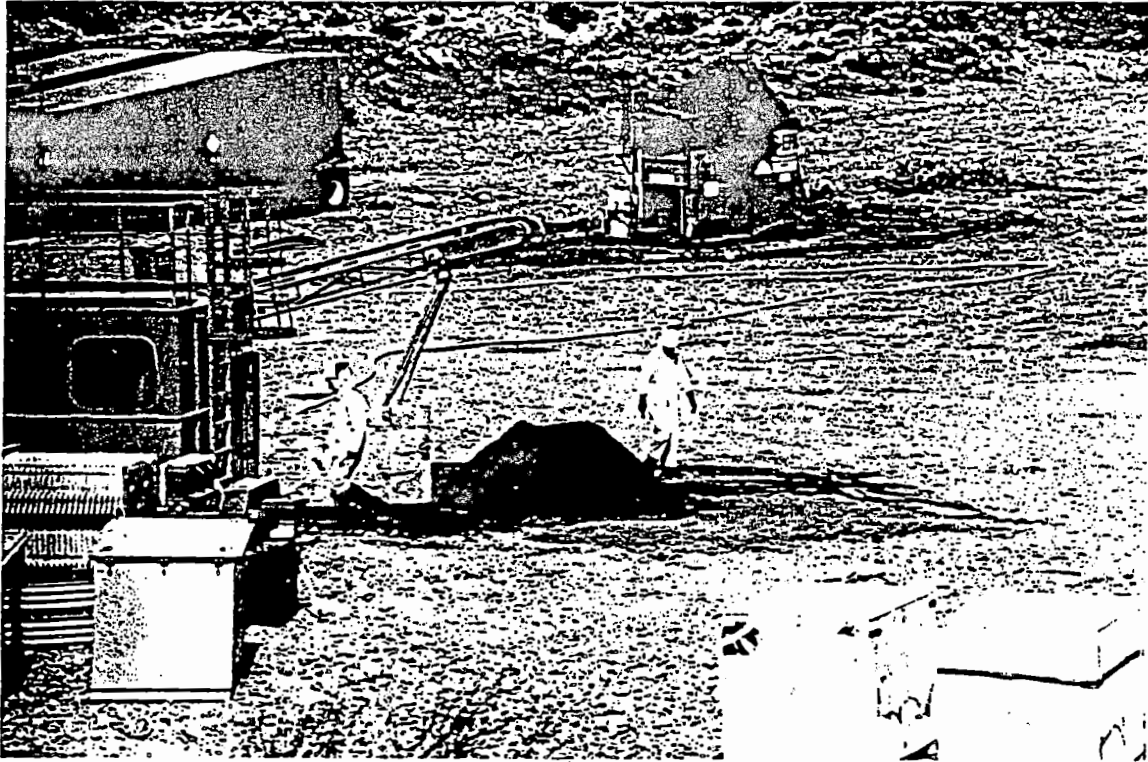


A. Loading the Feed Hopper.

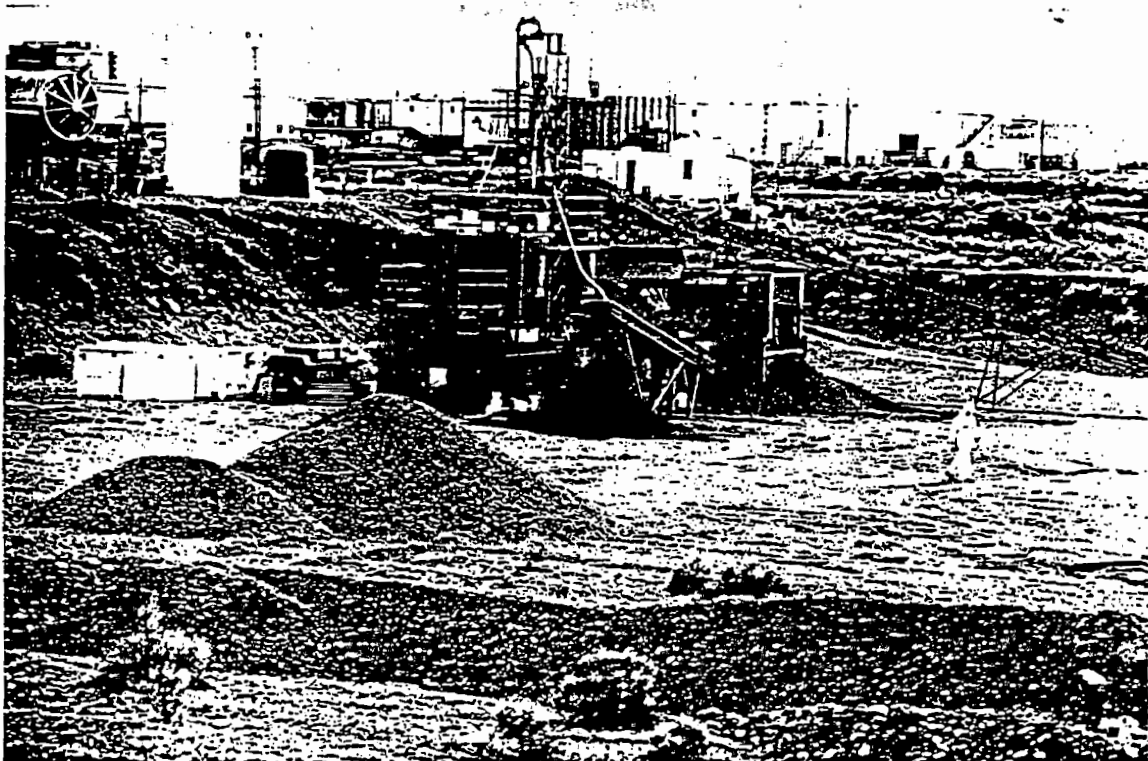


B. Feeding the Wet Screen.

Figure 3-4. Clean Product Production.



A. Sand Production.

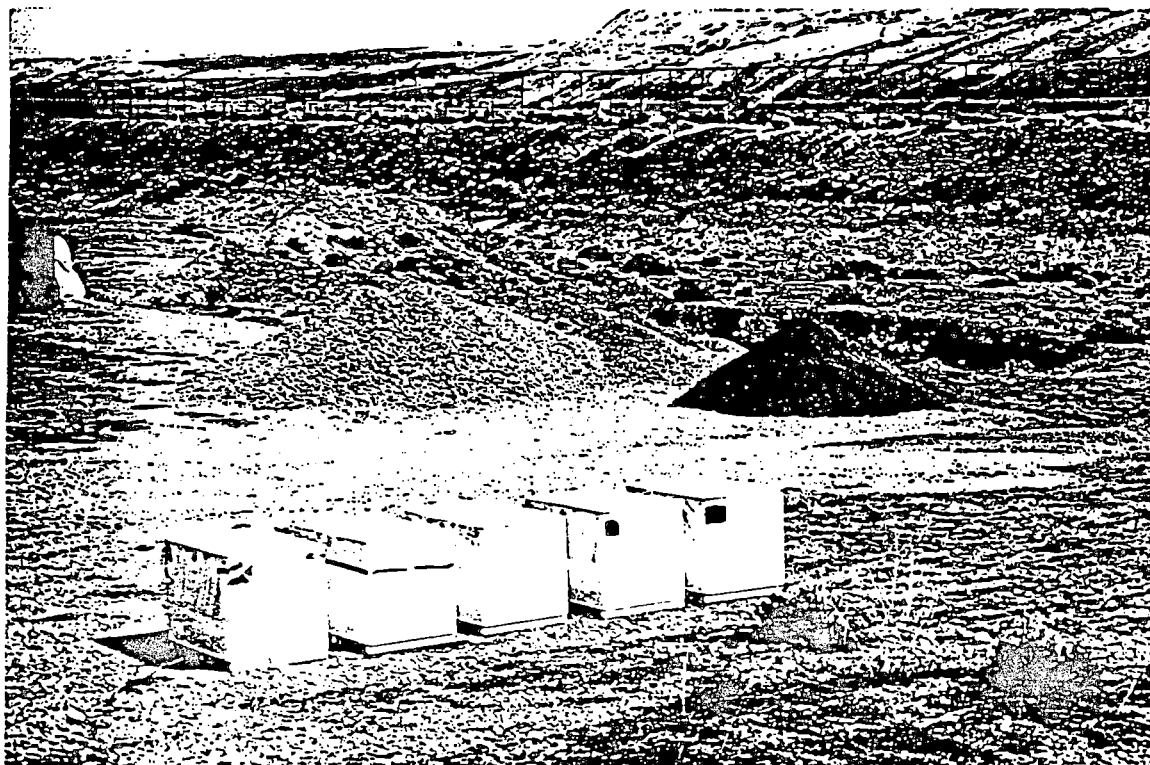


B. Sand and Oversize Production.

Figure 3-5. Pilot Study Products.

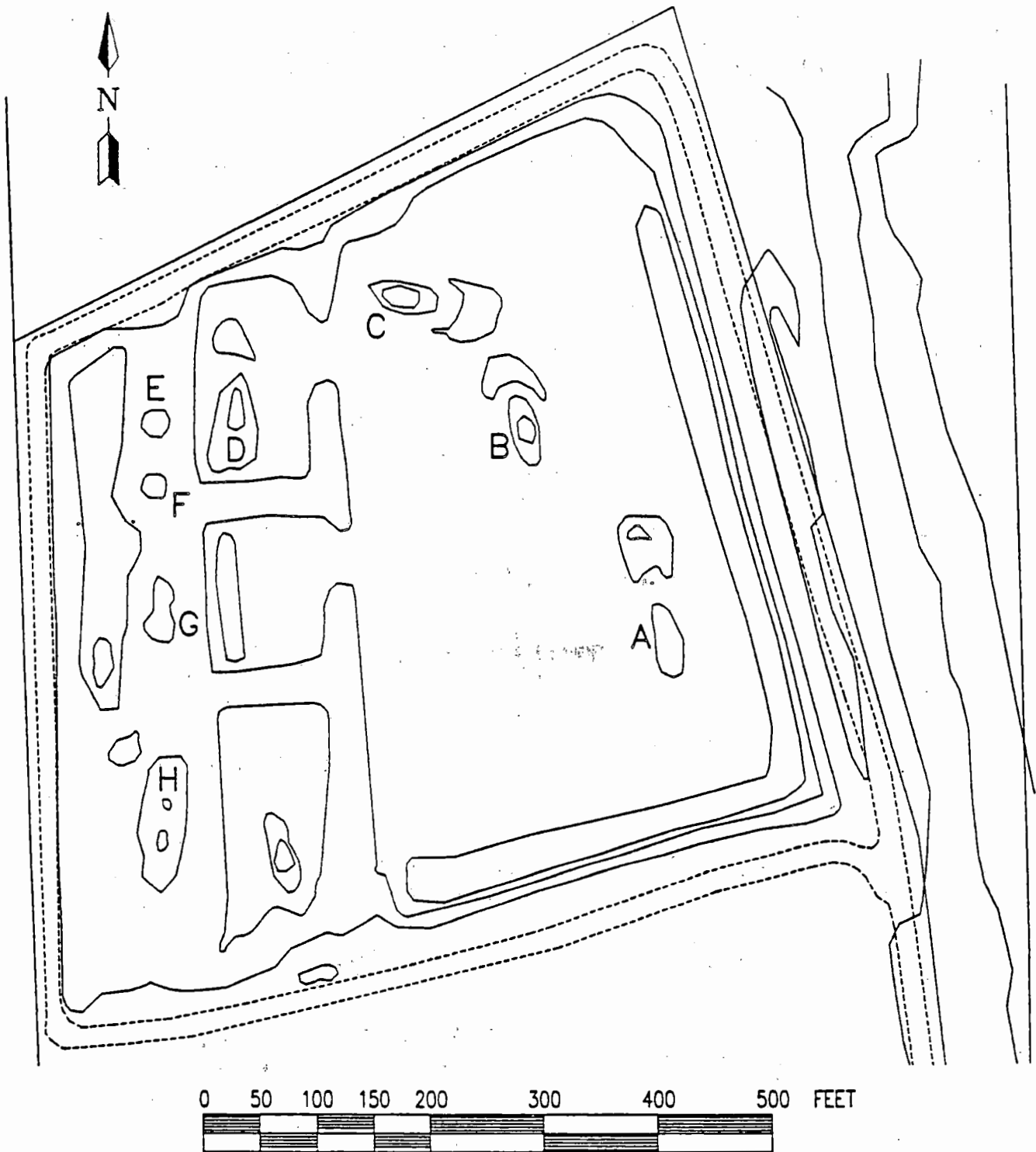


A. The Gross Oversize and Prescreened Feed.



B. Process Oversize, Sand, and Sludge Cake (in LSA Boxes).

Figure 3-6. Site Layout Showing Excavation Piles.



- A — C = LOCATION OF TEST PITS AS SOURCES OF SOIL FOR THE
PRE-TEST, VERIFICATION, & REPLICATION RUNS
E — G = LOCATION OF TEST PITS AS SOURCES OF SOIL FOR THE
URANIUM CARBONATE RUN

Source: WHC1994

Figure 3-7. Preprocessing Feed Material Particle Size Distribution.

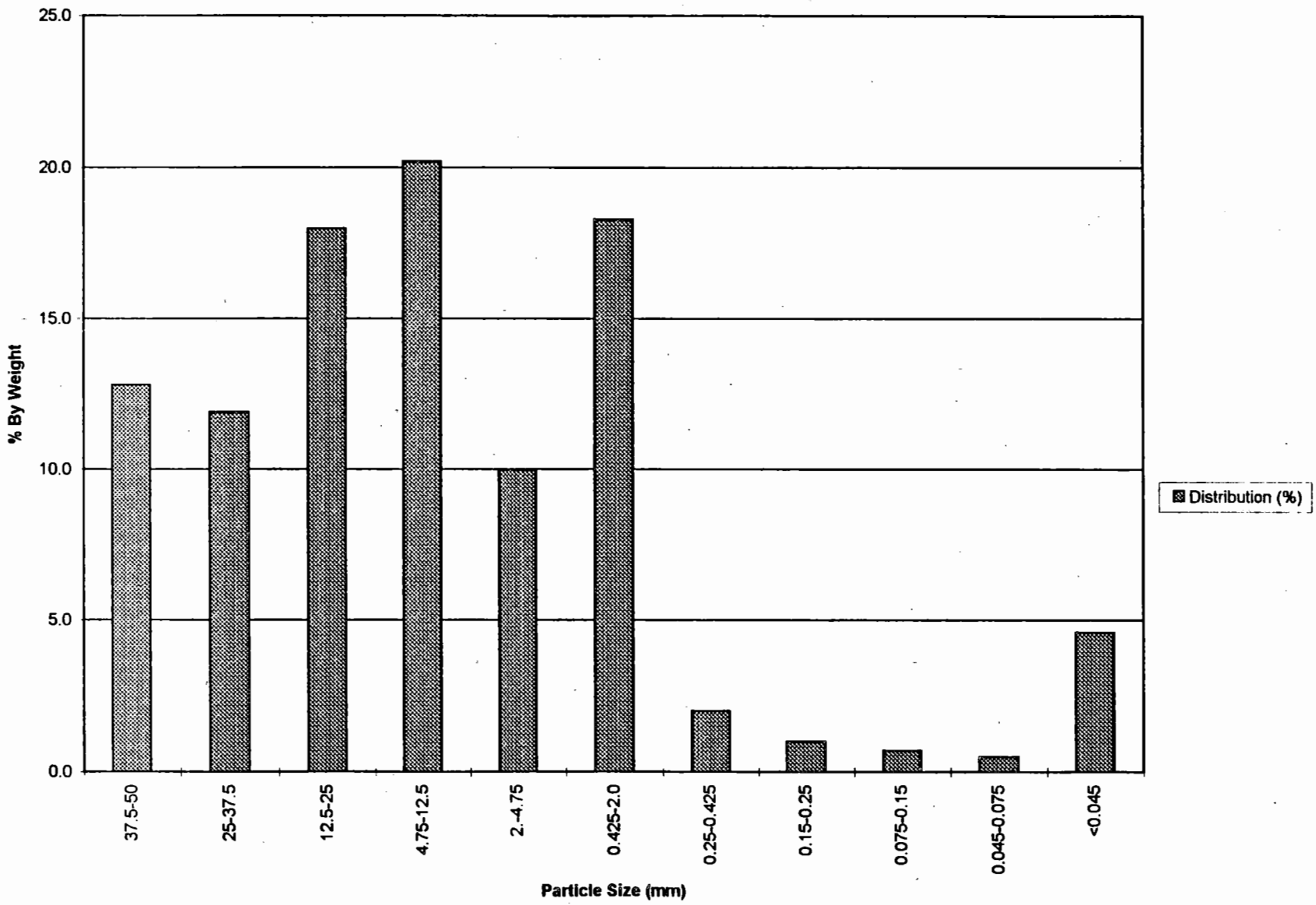


Figure 3-8. Feed Particle Size Distribution, Verification Run.

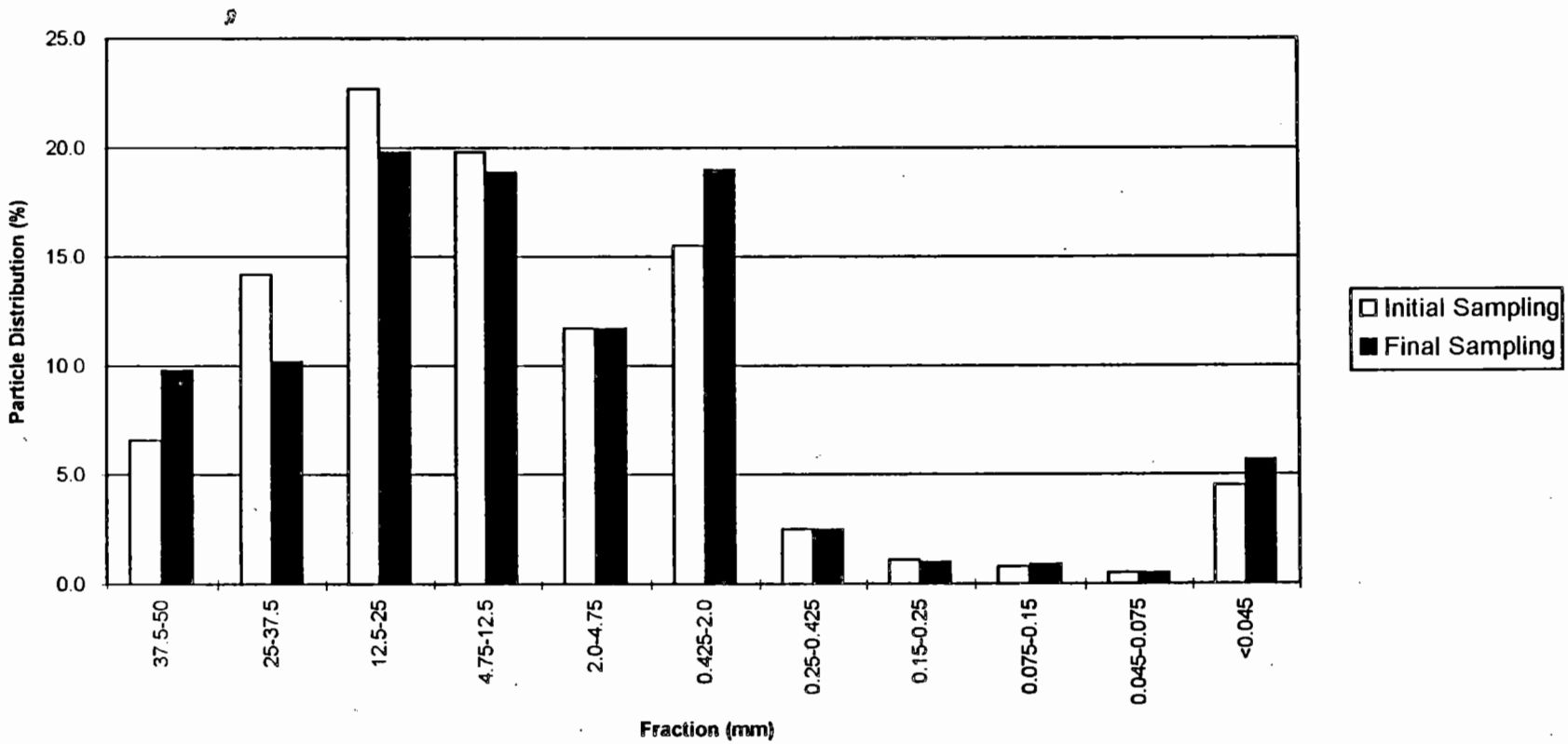


Figure 3-9. Copper Concentration and Distribution as a Function of Particle Size.

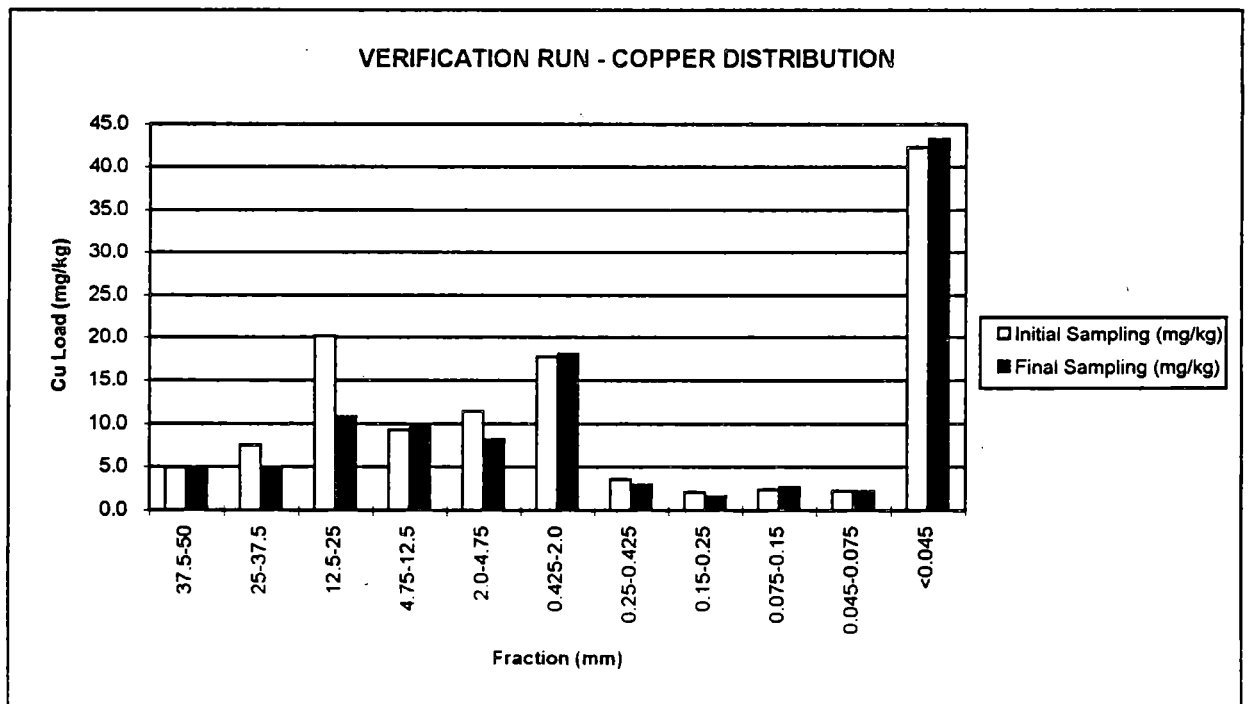
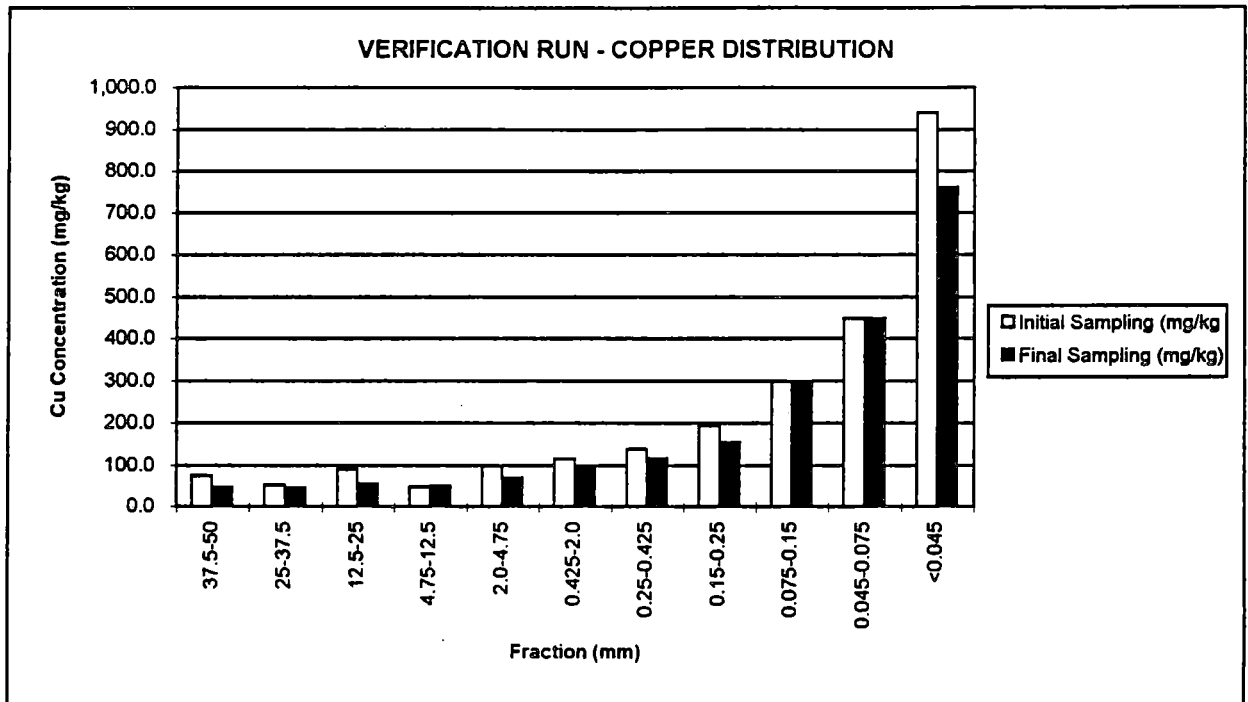
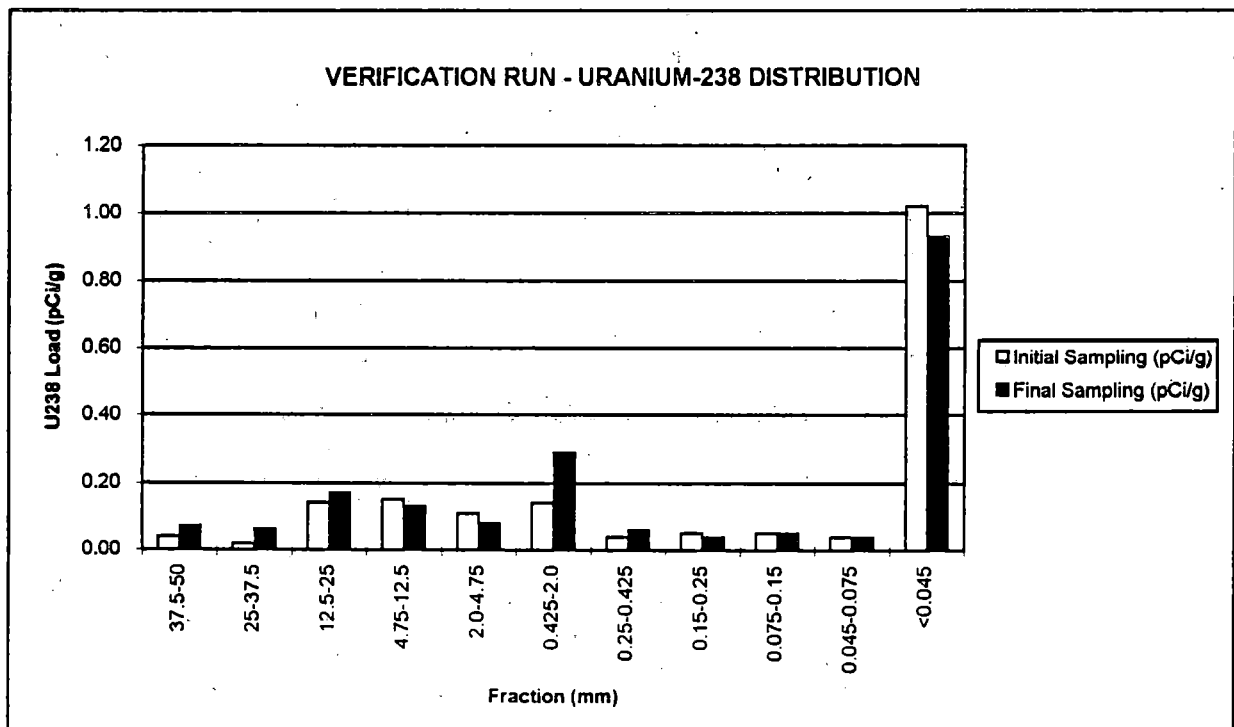
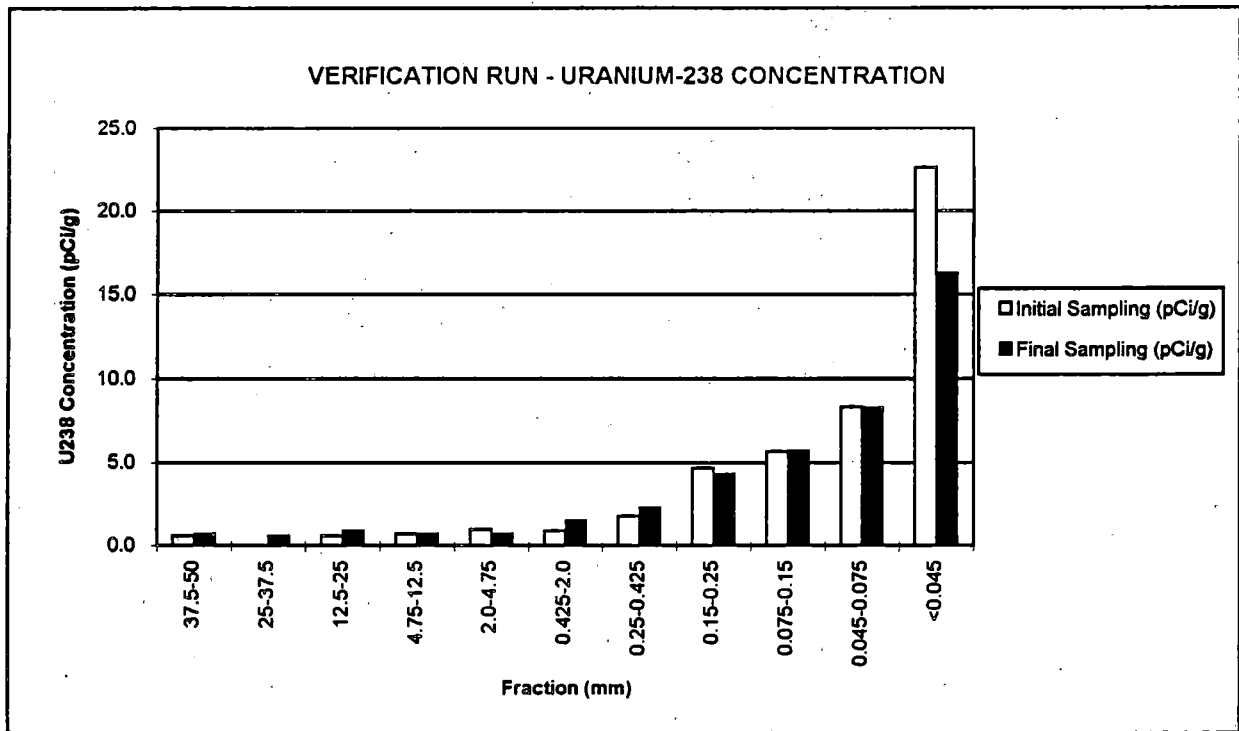


Figure 3-10. Uranium-238 Concentration and Distribution as a Function of Particle Size.



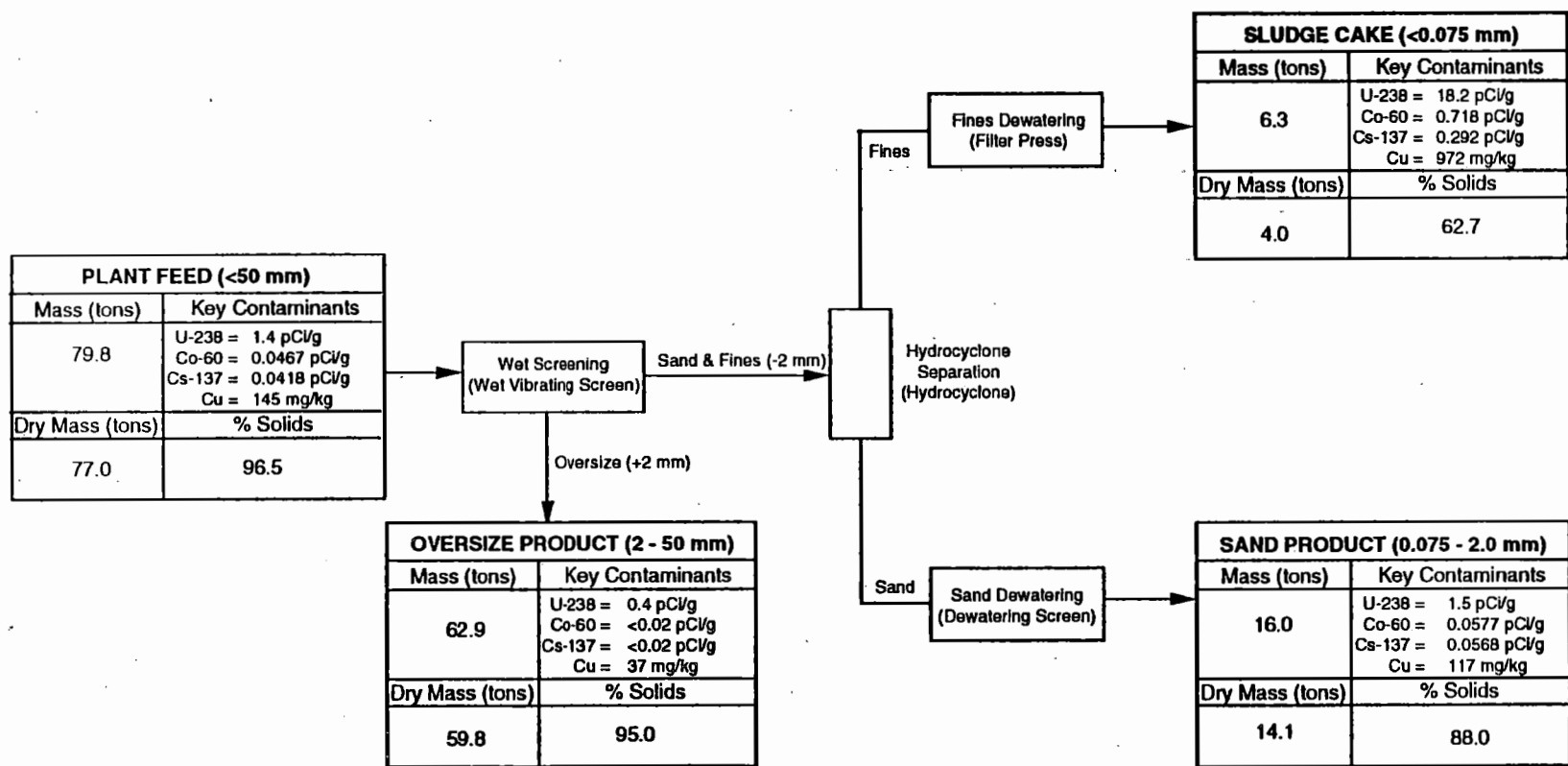


Figure 3-11. System/Mass Balance Diagram, Verification Run.

4413298-0347

Figure 3-12. Comparison of Calculated Soil Fraction Distribution Based on Feed Particle Size Distribution and Fraction Distribution of Field Test, Verification Run.

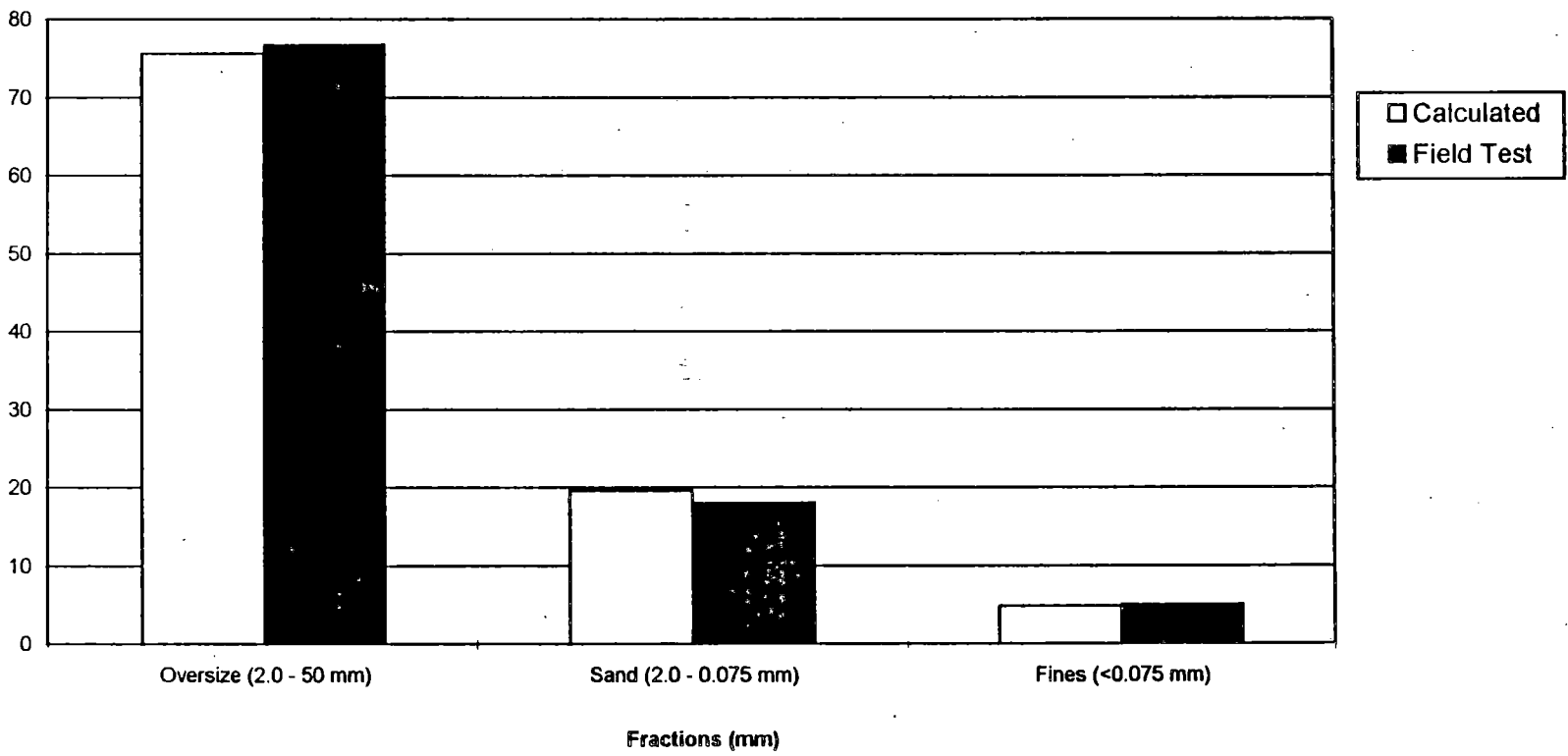


Figure 3-13. Feed Particle Size Distribution, Replication Run.

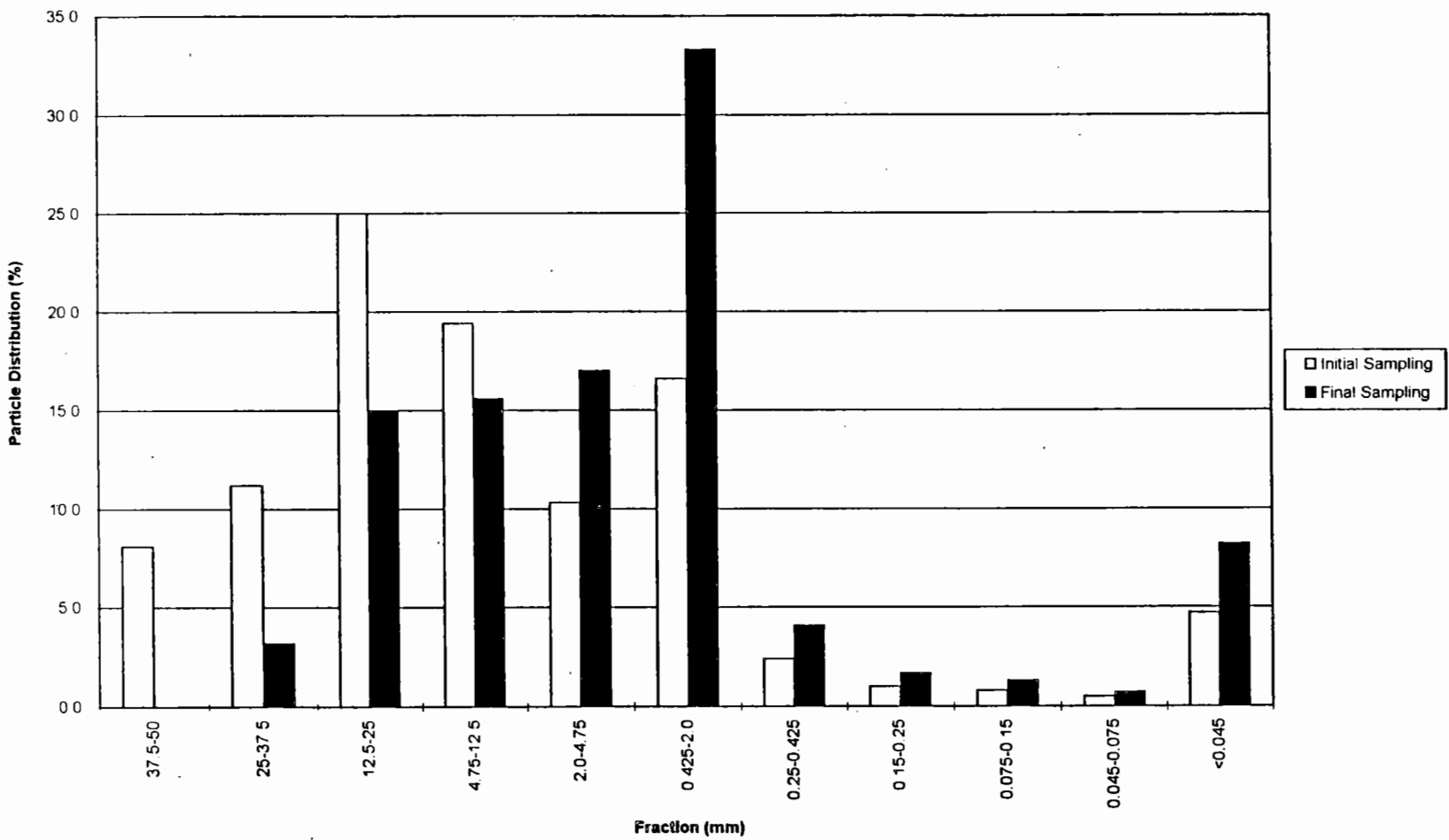


Figure 3-14. Copper Concentration and Distribution as a Function of Particle Size.

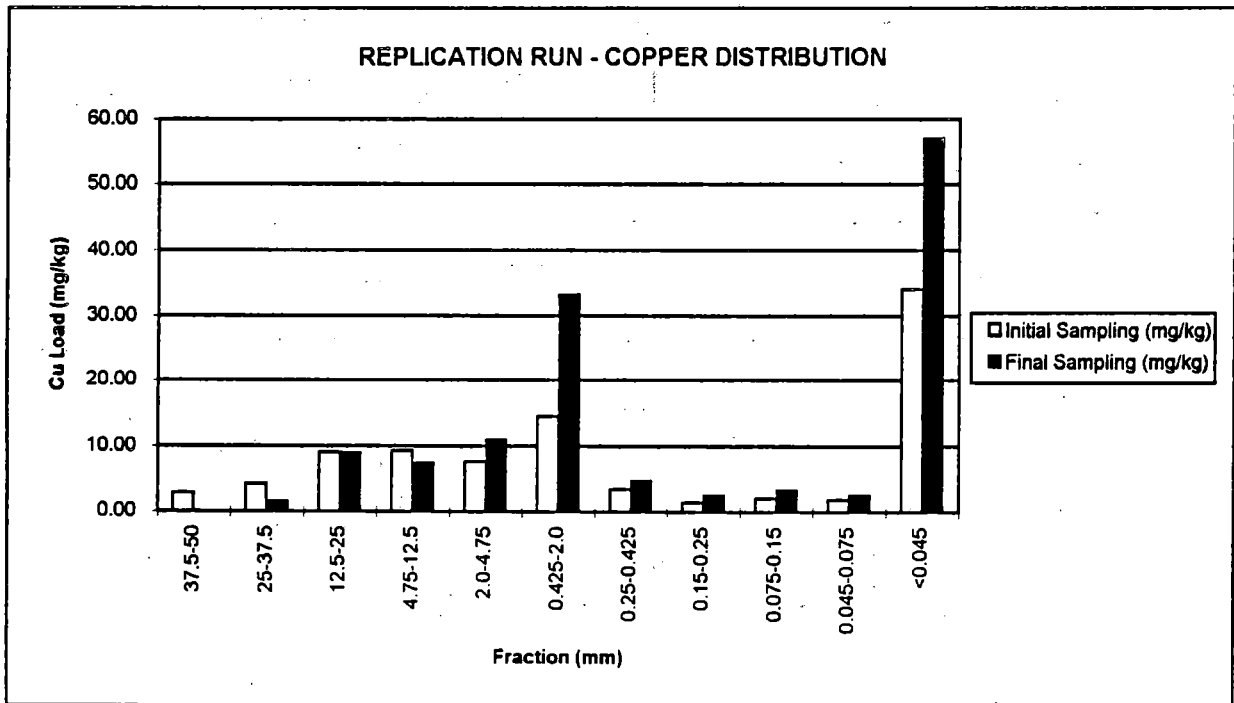
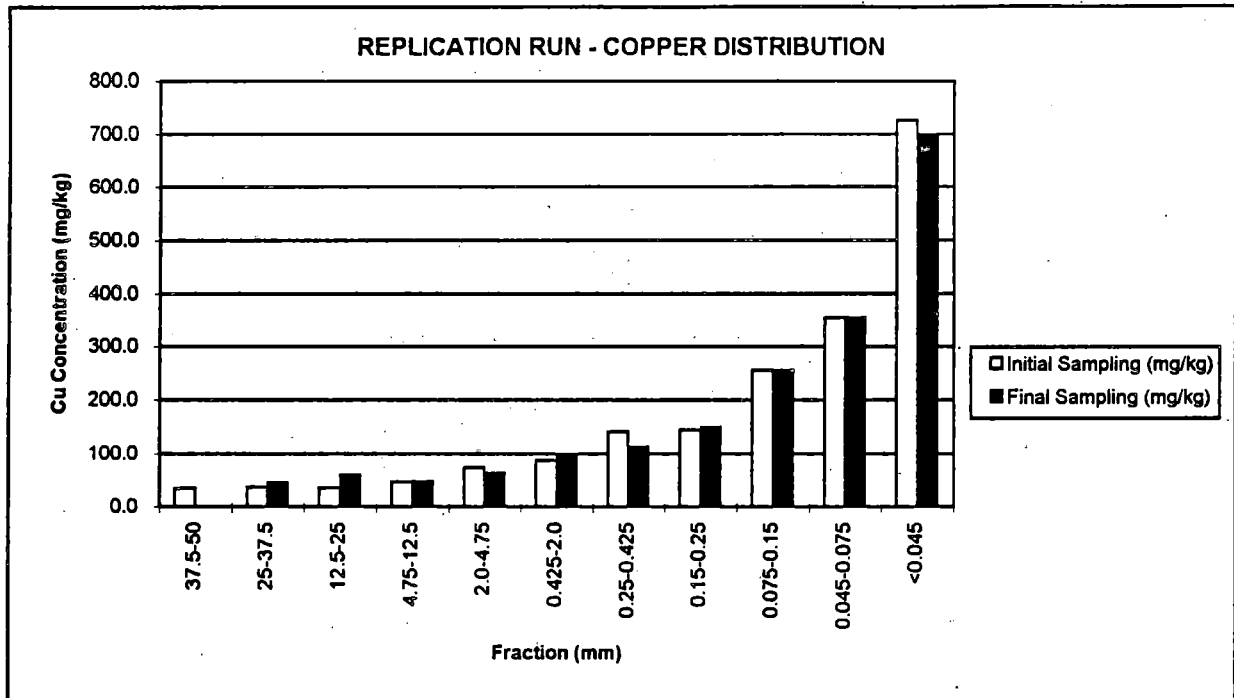


Figure 3-15. Uranium-238 Concentration and Distribution as a Function of Particle Size.

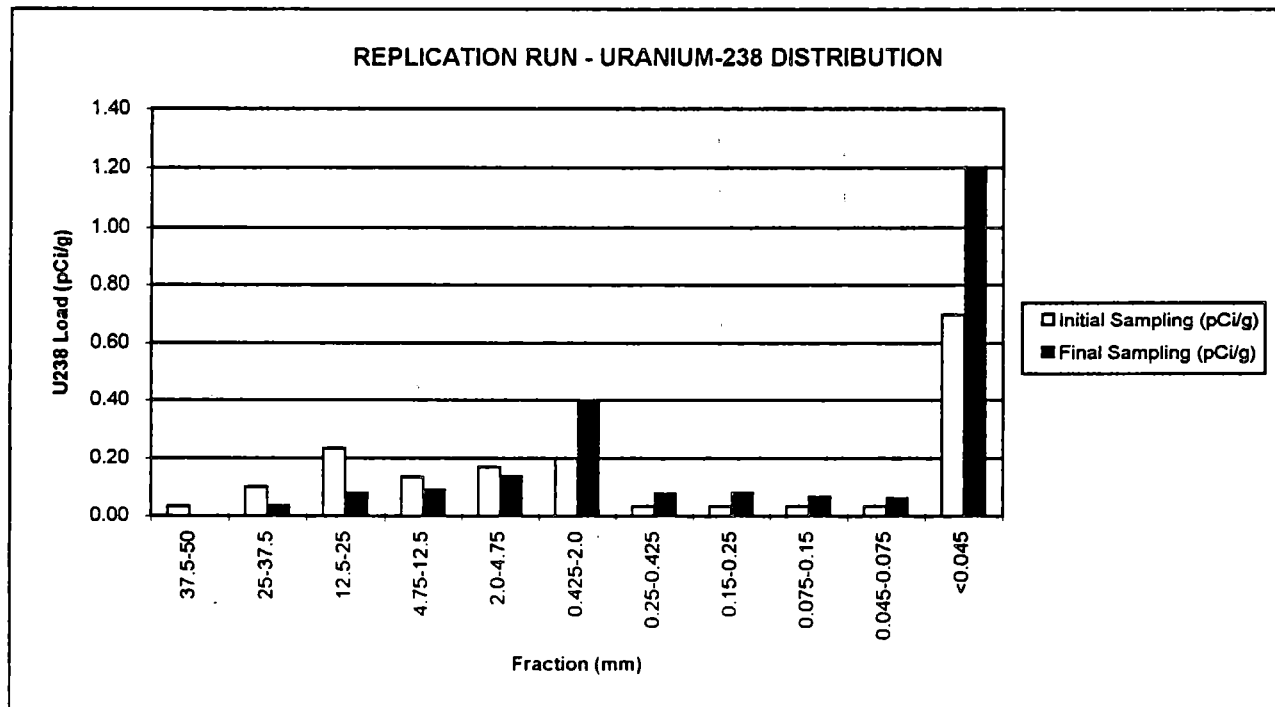
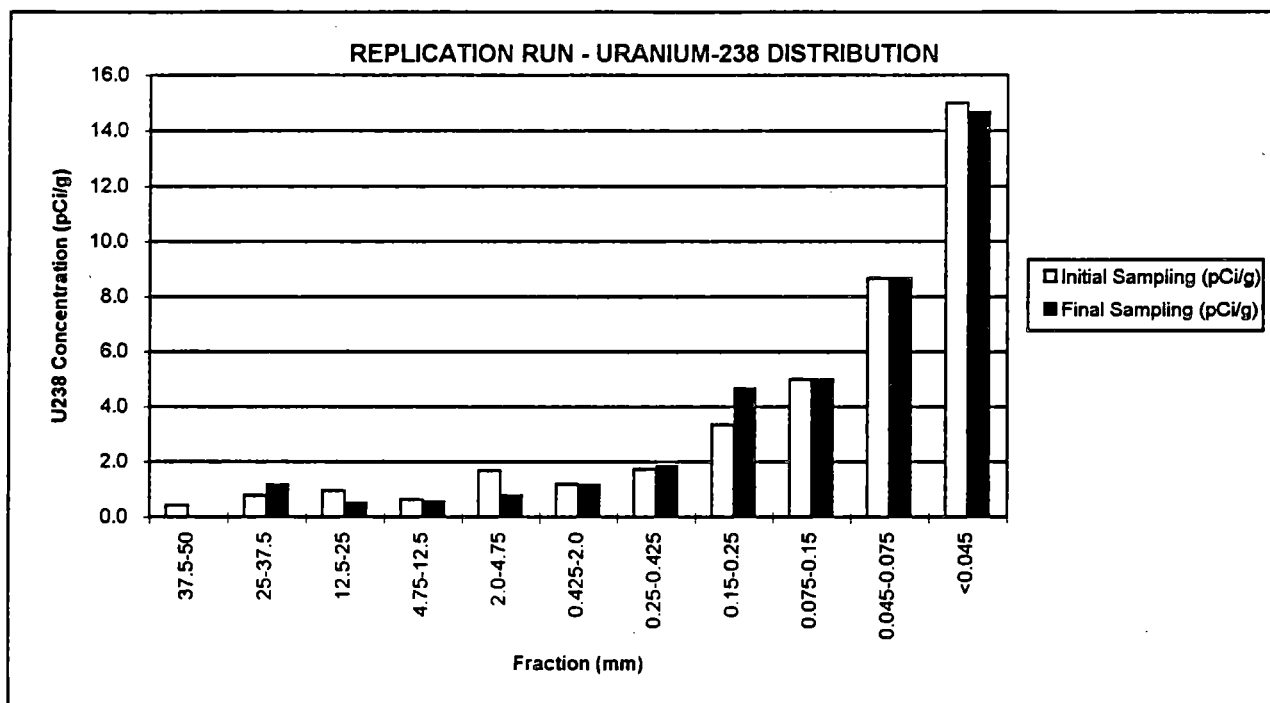


Figure 3-16. System/Mass Balance Diagram, Replication Run.

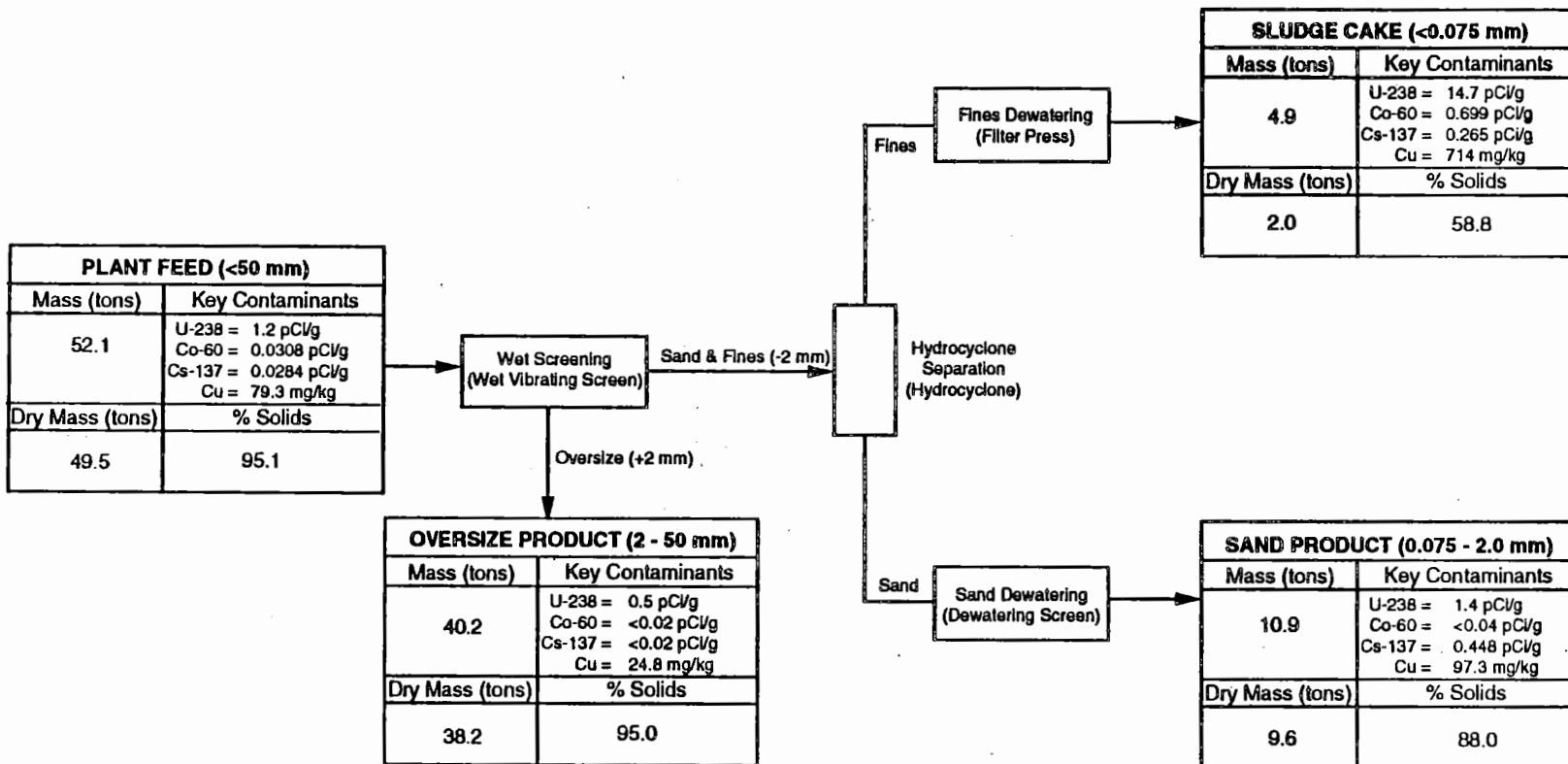


Figure 3-17. Comparison of Calculated Soil Fraction Distribution Based on Feed Particle Size Distribution and Fraction Distribution of Field Test, Replication Run.

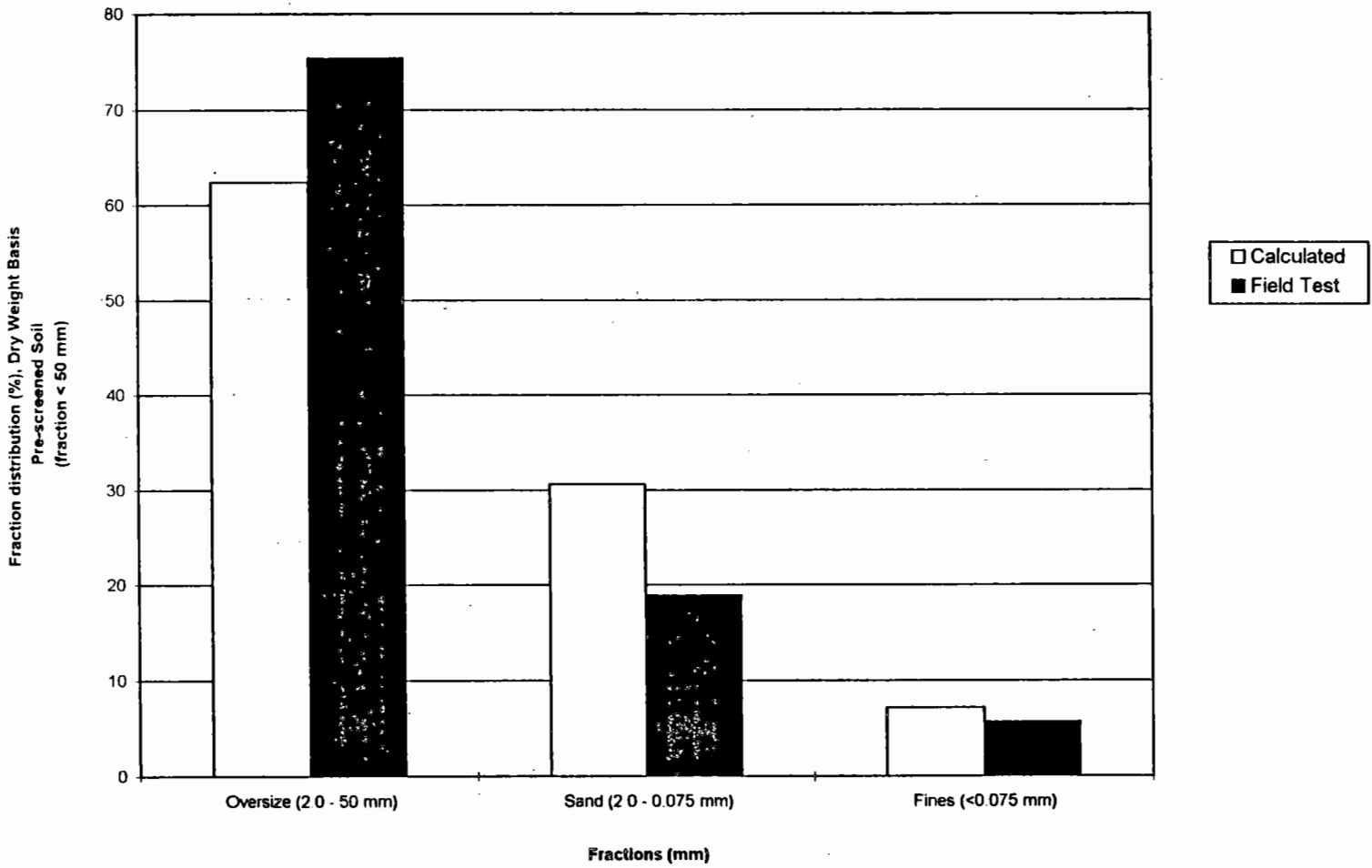


Figure 3-18. Feed Particle Size Distribution, Uranium Carbonate Run.

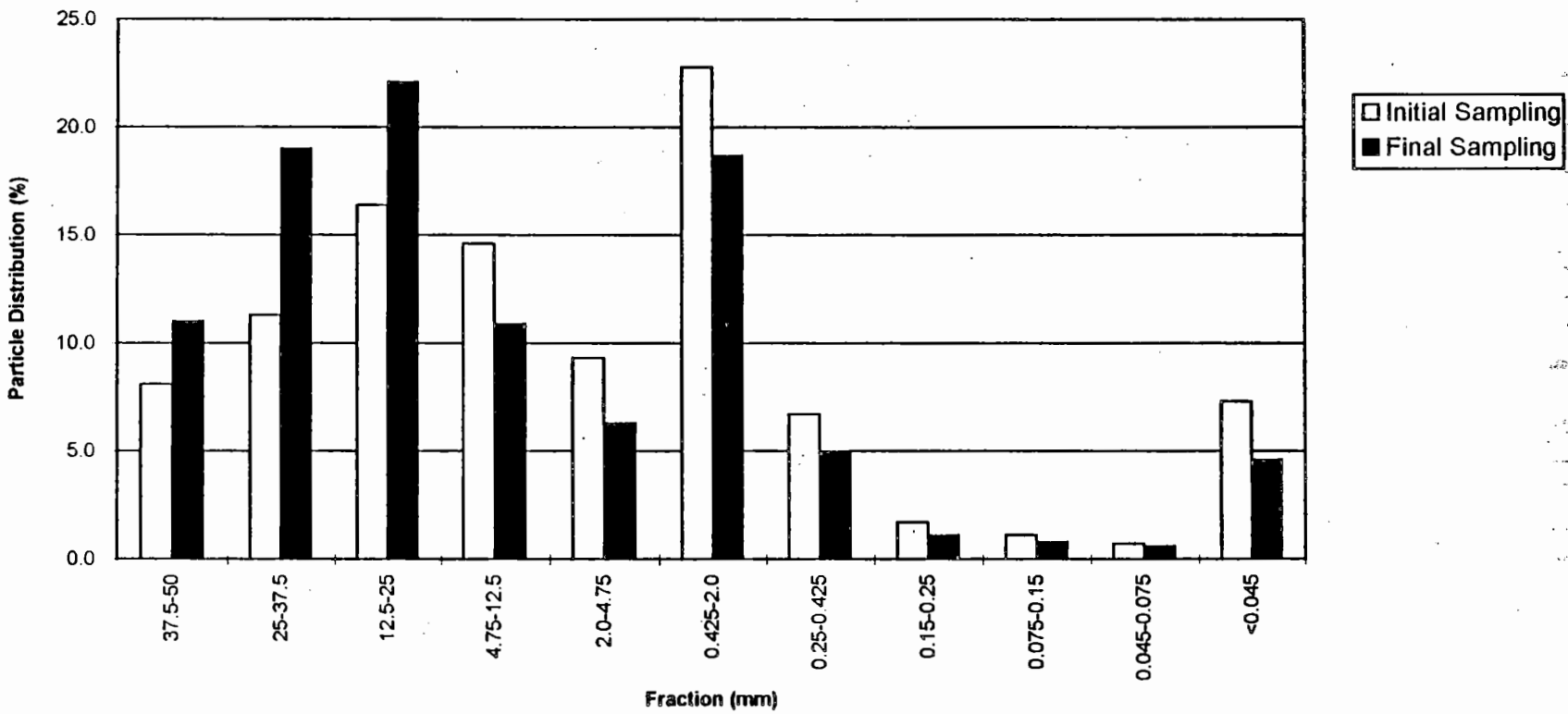


Figure 3-19. Copper Concentration and Distribution as a Function of Particle Size.

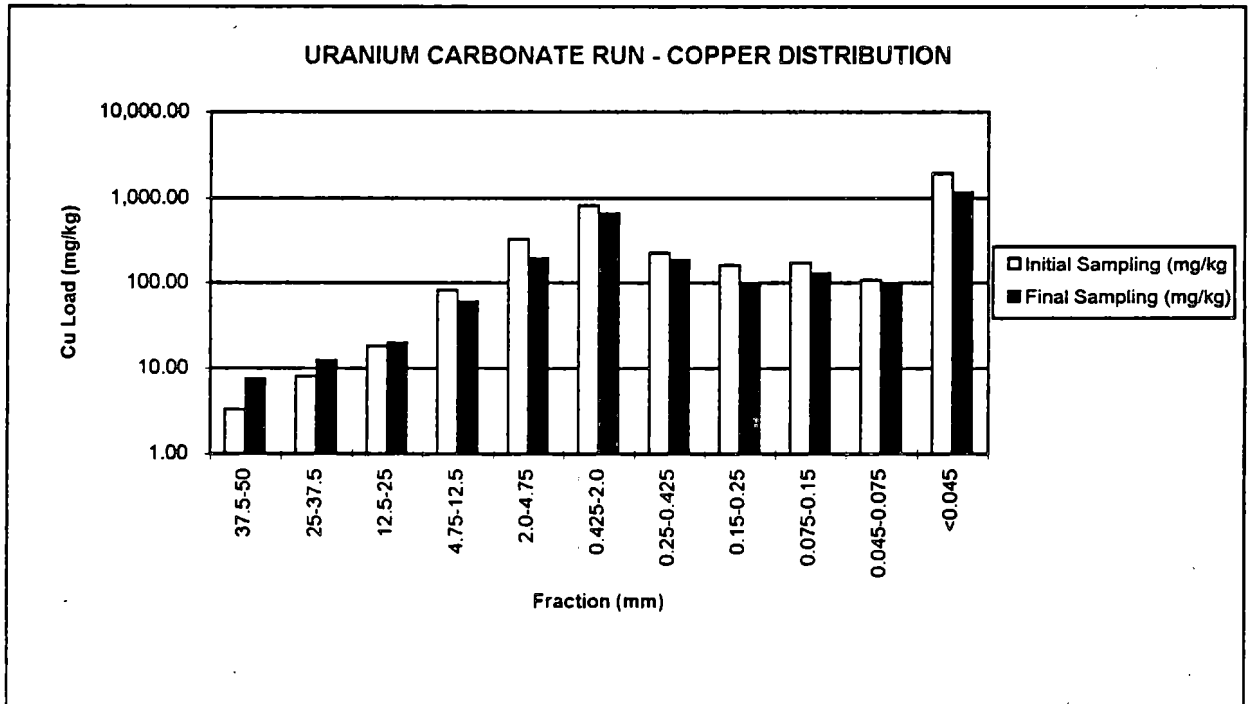
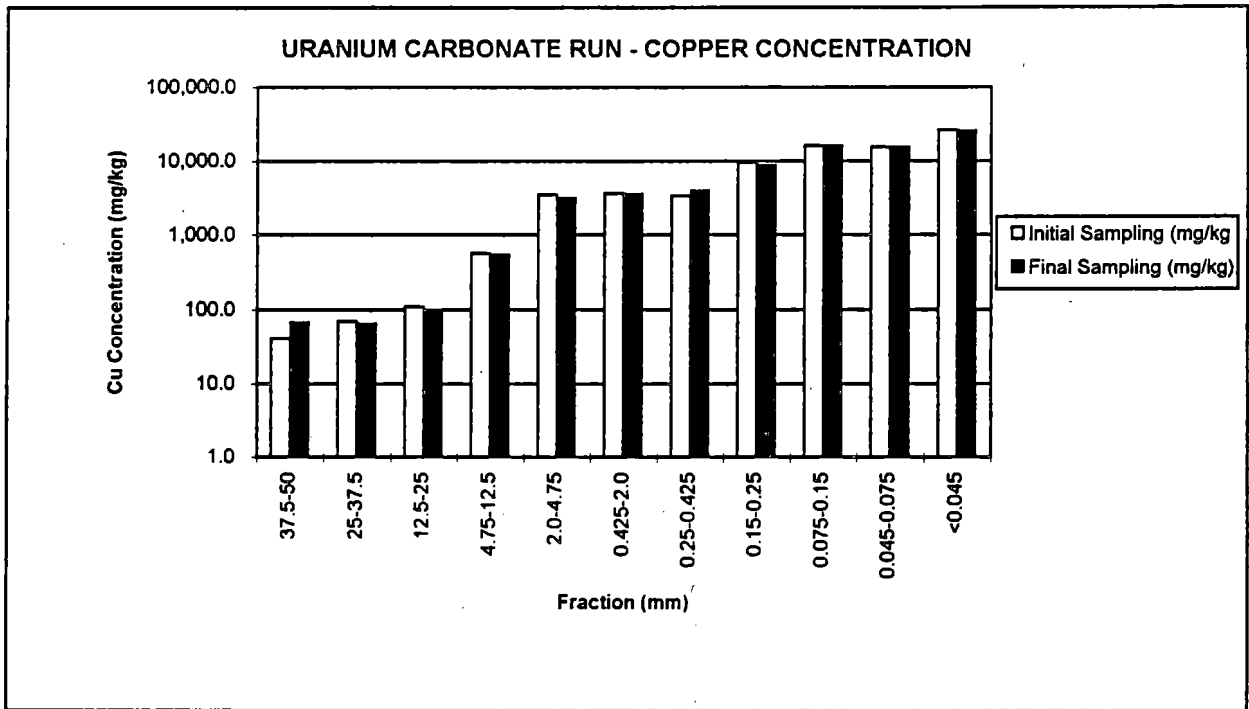


Figure 3-20. Uranium Concentration and Distribution as a Function of Particle Size.

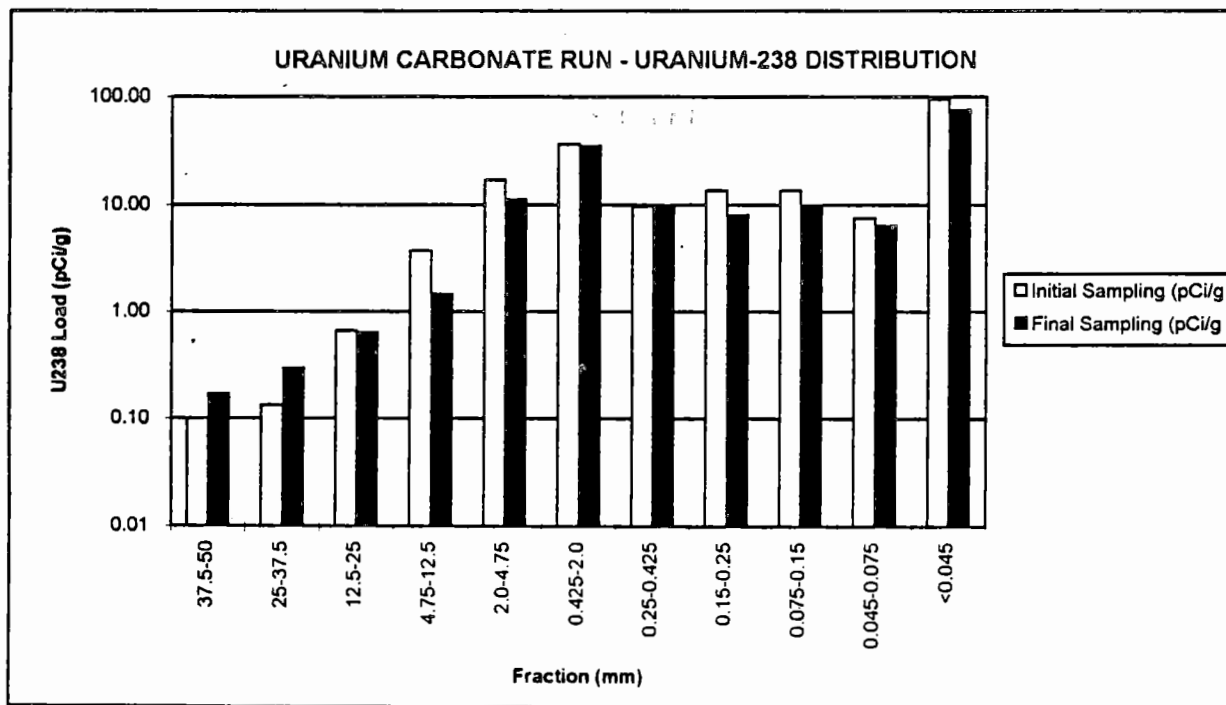
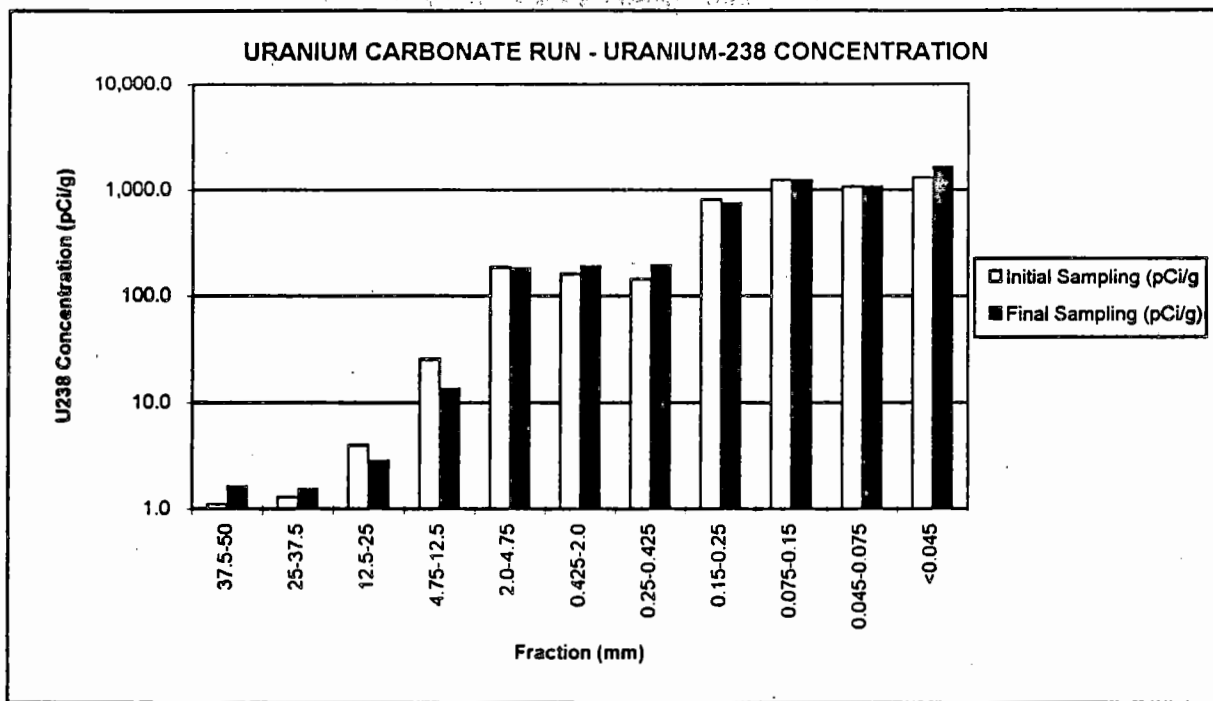
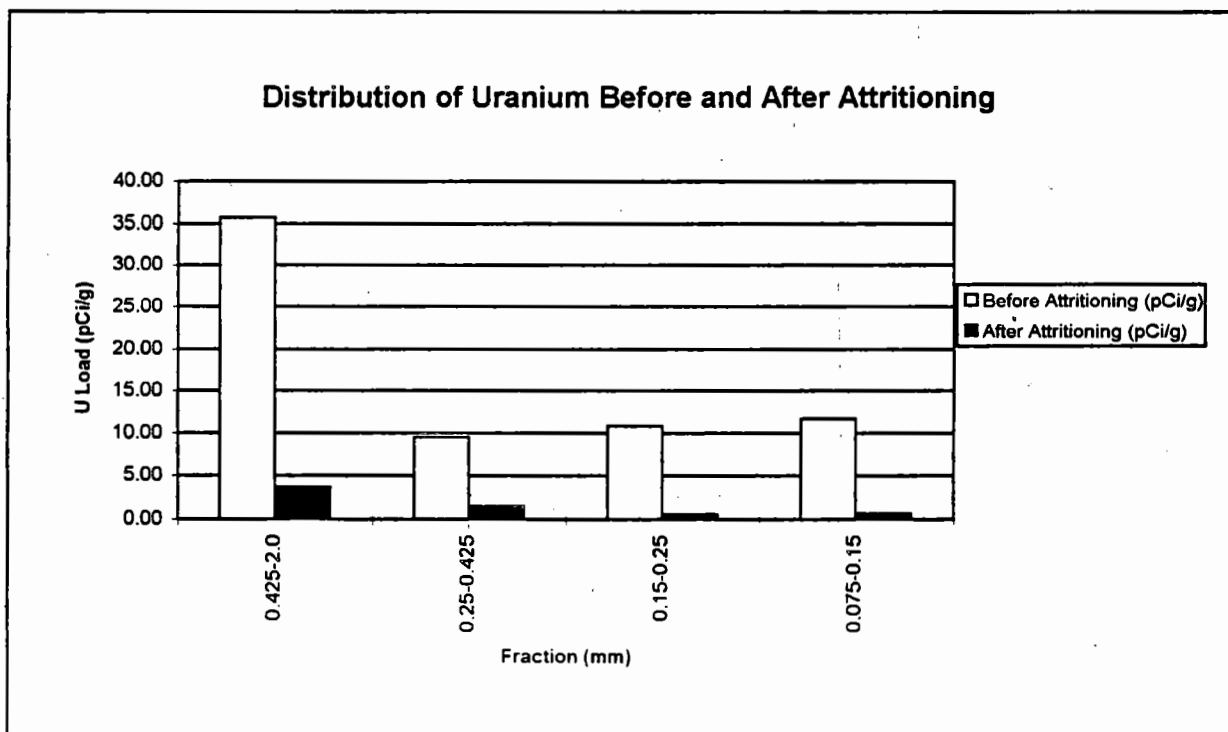
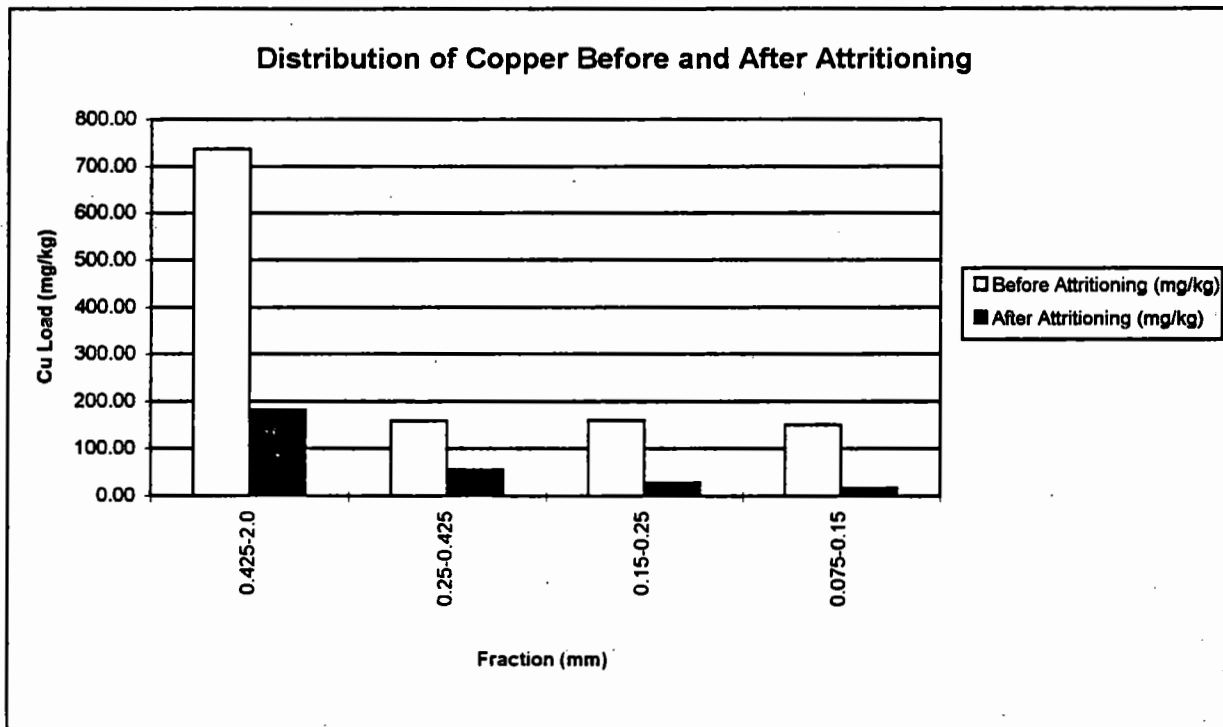


Figure 3-21. Distribution of Copper and Uranium in the Sand Product Before and After Attritioning.



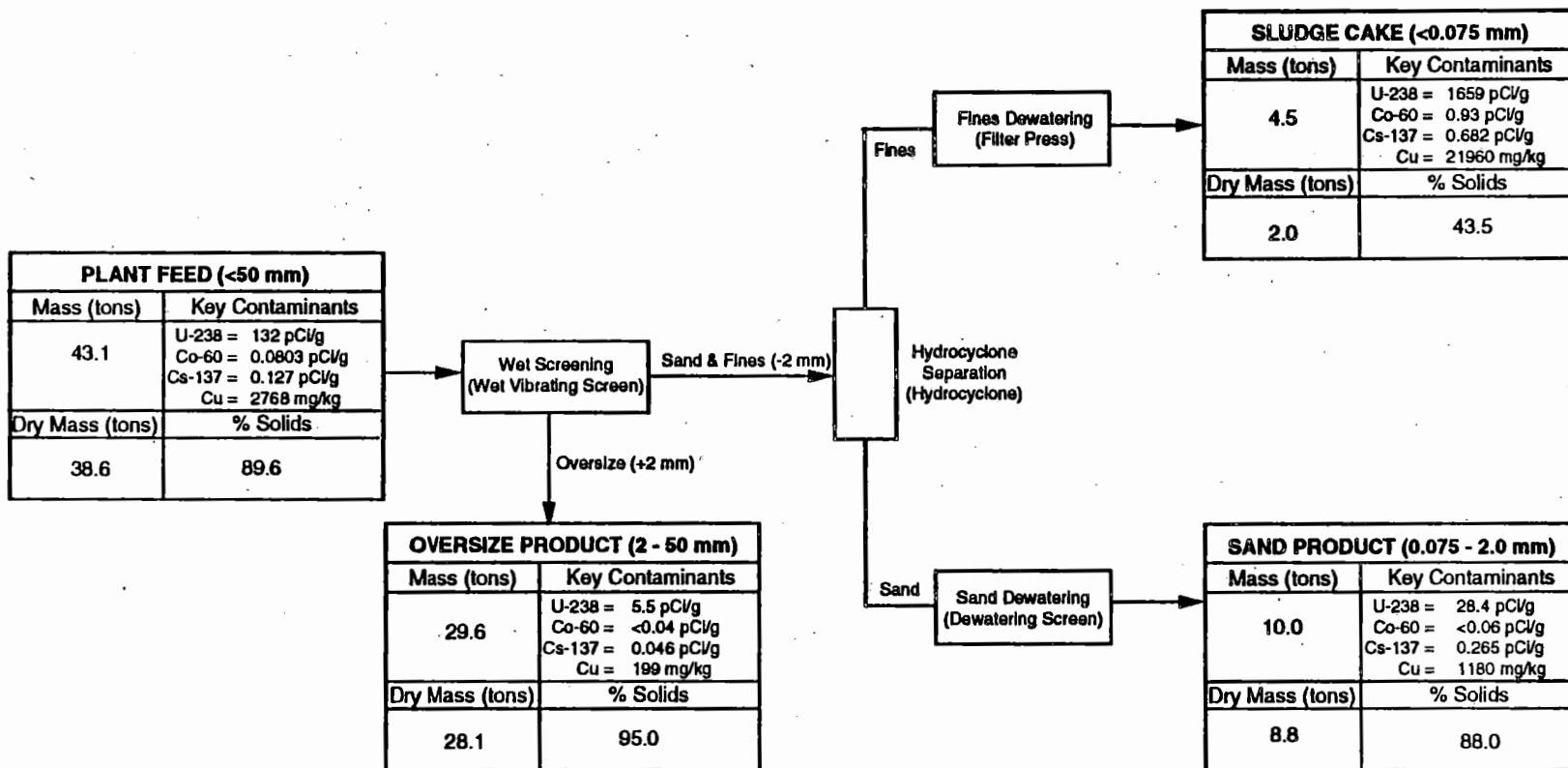


Figure 3-22. System/Mass Balance Diagram, Uranium Carbonate Run.

Figure 3-23. Comparison of Calculated Soil Fraction Distribution Based on Feed Particle Size Distribution and Fraction Distribution of Field Test, Uranium Carbonate Run.

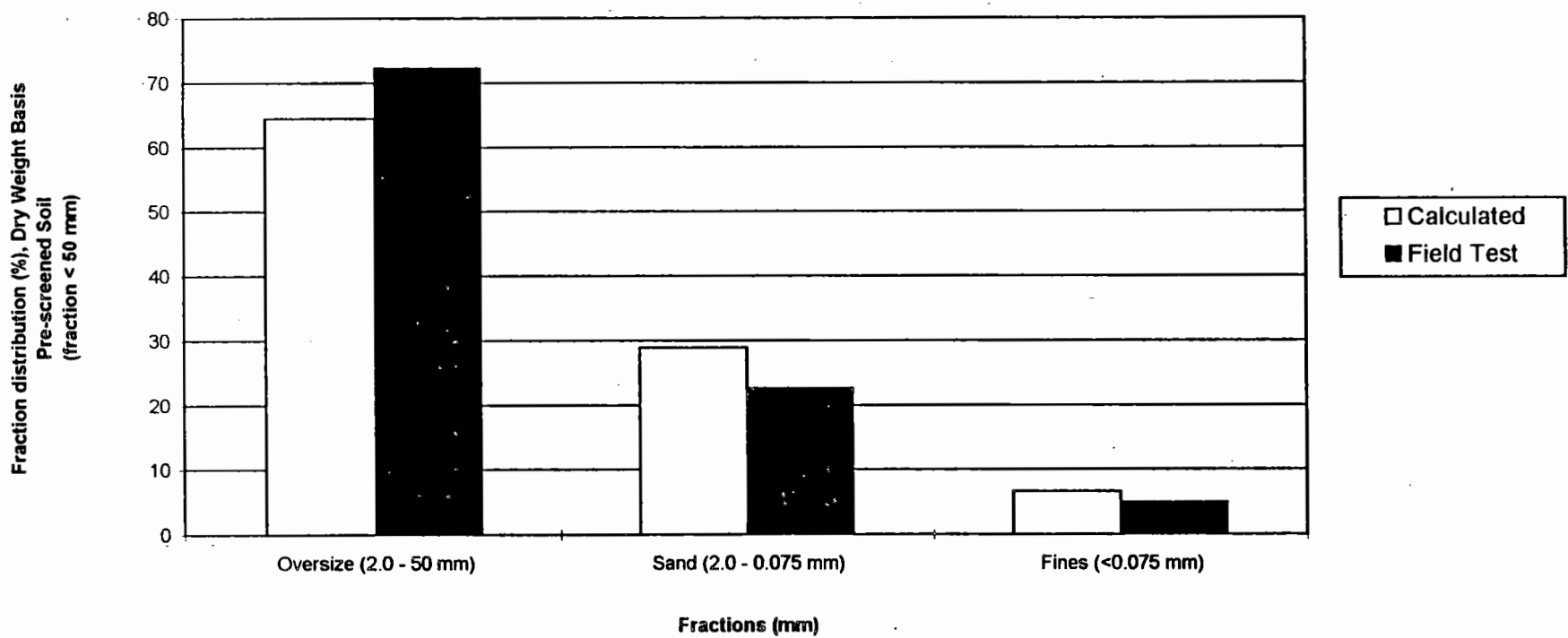


Figure 3-24. Feed Material Particle Size Distribution.

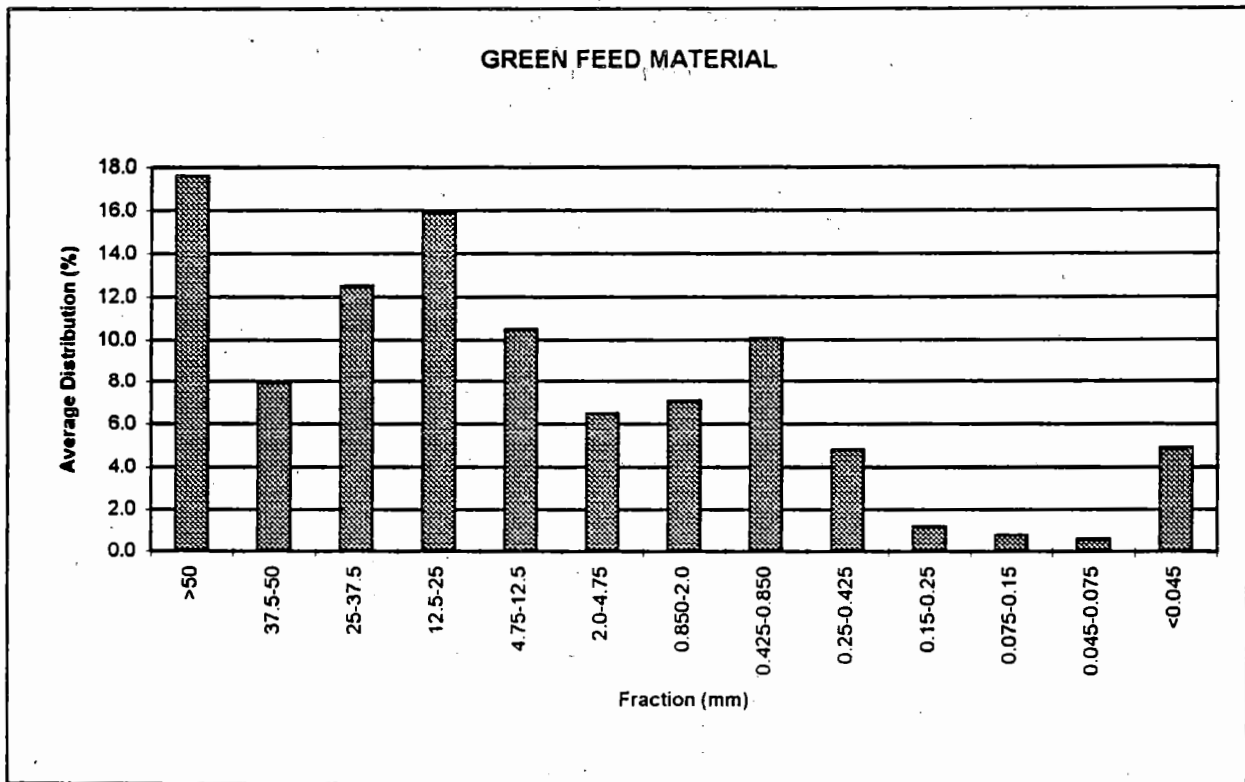
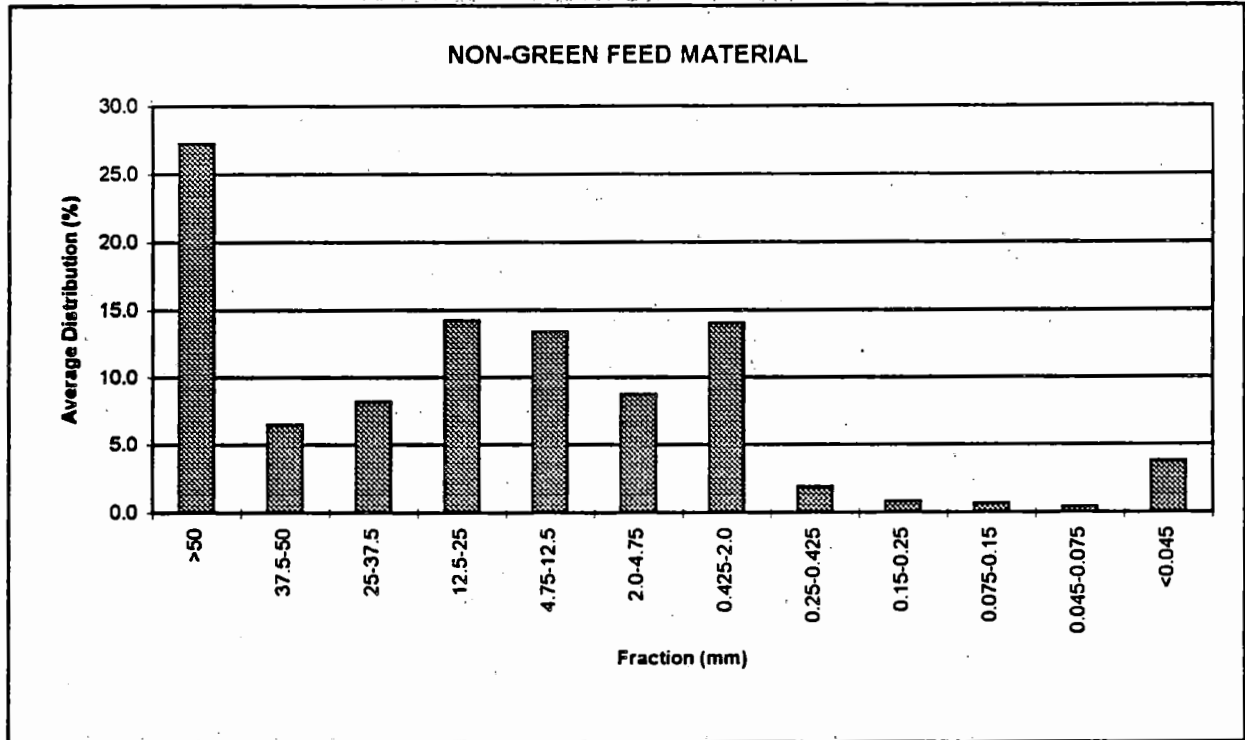


Table 3-1. Chronology of Events.

Date	Activity
February 10, 1994	Plan Approval
February 11, 1994	Training Complete
February 23, 1994	Plant Arrives at ATG
February 25, 1994	Plant Inspection Complete
March 16-25, 1994	Plant arrives and is assembled at RCA
March 28, 1994	Feed Screening Complete
March 28, 1994	Ready to Conduct Study
March 29, 1994	Pre-Test Runs
April 6, 1994	Verification Run
April 11, 1994	Replication Run
April 13, 1994	Uranium Carbonate Run
April 15, 1994	Plant Operations Complete
May 6, 1994	Sampling Activities Completed
May 17, 1994	Decontamination Activities Start
June 3, 1994	Decontamination Activities Complete, Plant Shipped Off-site
June 10, 1994	Analytical Data Received
June 15, 1994	Draft Report Submitted to WHC
July 29, 1994	Final Report Submitted to Bechtel Hanford, Inc.

Table 3-2. Prescreening Mass Balance for Soils not Containing Green Uranium Carbonate Material (Used as Feed for Pretest, Verification, and Replication Runs).

Product	Mass (tons)	Distribution (%)
Total Soils Processed	273.2	
Gross Oversize (>50 mm)	74.5 ^A	27.3
Plant Feed (<50 mm)	<u>198.7</u>	<u>72.7</u>
Total	273.2	100.0
Recovery (%) ^B	100.0	

^A Portion of greater than 50-mm fraction after screening could not be recovered for weighing.
Mass for this fraction has been calculated "by difference".

^B Recovery defined as total weight of recovered products as a percentage of feed weight.

Table 3-3. Prescreening of Soils Containing Green Uranium Carbonate Material.

Product	Mass (tons)	Distribution (%)
Total Soils Processed	75.0	
Gross Oversize (>50 mm)	12.8	17.6
Plant Feed (<50 mm)	<u>60.1</u>	<u>82.4</u>
Total	72.9	100.0
Recovery (%) ^A	97.2	

^A Recovery defined as total weight of recovered products as a percentage of feed weight.

Table 3-4. Results of the Chemical and Radiochemical Analysis of the Gross Oversize Fraction (Material > 50 mm) from the Pretest, Verification, and Replication Runs.

Sample Name	Sample Identification	Silver	Aluminum	Beryllium	Cadmium	Chromium	Copper	Iron	Mercury	Manganese	Nickel	Lead	Antimony	Zinc	Uranium
Washwater from Sample HPGSL-1 (ug/L)	HPGWA-1	9.1 J	12700	0.60	<2.6 U/J	21.2	304 J	14500	0.50	317 J	38.5 J	6.0 J	<25.4	68.7 J	30
Washwater from Sample HPGSL-2 (ug/L)	HPGWA-2	8.8 J	8300	0.30	<2.6 U/J	25.1	590 J	9230	1.0	262 J	44.5 J	98 J	38.1	60.8 J	84
Washwater from Sample HPGSL-3 (ug/L)	HPGWA-3	4.4 J	5800	0.50	<2.6 U/J	14.6	178 J	7320	0.53	168 J	24 J	4.7 J	31.8	43.5 J	35
Washed Solids from Samples HPGSL-1, HPGSL-2 and HPGSL-3 (mg/kg)	HPGSL-4	7.3	8750	0.57	<0.49	23.3	508	22800	0.46 J	454	40.3	6.4 J	<4.8	63.8	20
Washed Gross Oversize from HPGSL-1 (XRF)	HPGSL-5	---	---	---	---	---	---	---	---	---	---	---	---	---	4.4
Washed Gross Oversize from HPGSL-2 (XRF)	HPGSL-6	---	---	---	---	---	---	---	---	---	---	---	---	---	1.7
Washed Gross Oversize from HPGSL-3 (XRF)	HPGSL-7	---	---	---	---	---	---	---	---	---	---	---	---	---	2.5
Calculated Parameter															
Mass of Each Constituent in the Washwater Sample (mg)	Volume of Washwater (L)														
HPGSL-1	3.76	0.034	47.75	0.0023	<0.01	0.080	1.14	54.5	0.0019	1.19	0.14	0.023	<0.1	0.26	0.11
HPGSL-2	3.58	0.032	29.71	0.0011	<0.01	0.090	2.11	33.0	0.0036	0.94	0.16	0.351	0.14	0.22	0.30
HPGSL-3	3.91	0.017	22.68	0.0020	<0.01	0.057	0.70	28.6	0.0021	0.66	0.09	0.018	0.12	0.17	0.14
Mass of Each Constituent in the Washed Solids (mg)	Dry Weight (kg)														
	0.89	6.5	7804.9	0.5	<0.5	20.8	453	20337	0.4	405.0	35.9	6	<4.5	56.9	17.8
Total Mass of Metals Removed From Gross Oversize (mg)		6.6	7905.1	0.5	<0.5	21.0	457	20454	0.4	407.8	36.3	6	<4.5	57.6	18.4
Total Concentration of Metals Removed on a Weight Basis (mg/kg)	Total Mass of Oversize (kg)														
	86.8	0.076	91.1	0.0059	<0.006	0.242	5.27	236	0.0048	4.70	0.419	0.07	<0.05	0.663	0.21
Average Bulk Concentration (mg/kg)		---	---	---	---	---	---	---	---	---	---	---	---	---	2.9
Background Concentration (mg/kg)															
Reference 1		<1.0	9910	0.65	0.5	9.8	18.4	27620	<0.1	396.2	7.6	5.08	<10	50.2	NA
Reference 2		1.53	3070	0.25	0.59	5	10.7	11300	0.049	189	3.8	1.55	5.01	11.5	0
Reference 3															1.8
Test Performance Criteria (mg/kg)		960	NA	172	320	1600	11840	NA	96	64000	6400	4480	128	64000	155
Concentration of Metals Removed as Percentage of Test Performance Criteria		<0.01	NA	<0.01	<0.01	0.015	0.04	NA	<0.01	<0.01	<0.01	0.00	<0.01	<0.01	0.14

Reference 1 Background Levels are values used for risk calculations from Phase I RI report (DOE-RL 1993c)

Reference 2 Background Levels are taken from Dennison et al (1989)

Reference 3 Uranium Background values taken from internal WHC communication from Scott W Petersen to Roberta Day, Subject Preliminary Radionuclide Background in Soils

Table 3-5. Results of the Chemical and Radiochemical Analysis of the Gross Oversize Fraction (Material > 50 mm) from the Uranium Carbonate Run.

Sample Name	Sample Identification	Silver	Aluminum	Beryllium	Cadmium	Chromium	Copper	Iron	Mercury	Manganese	Nickel	Lead	Antimony	Zinc	Uranium
Washwater from Sample HPGSL-8 (ug/L)	HPGWA-4	588	138000	4.8	16	2330	47900	29600	44.3	976	3520	658	37.2	1190	19,400
Washed Solids from Sample HPGSL-8 (mg/kg)	HPGSL-9	63.5	18000	0.049	2.9	297	5720	12600	11.8	212	440	46	9.5	134	2,100
Calculated Parameter															
Mass of Each Constituent in the Washwater Sample (mg)	Volume of Washwater (L) 1.75	0.991	241.50	0.0084	0.0280	4.078	83.83	51.8	0.0775	1.71	6.16	1.152	0.065	2.08	33.95
Mass of Each Constituent in the Washed Solids (mg)	Dry Weight (kg) 0.46	29.2	8265.6	0.0	1.3	136.4	2627	5786	5.4	97.4	202.0	21	4	61.5	984.3
Total Mass of Metals Removed From Gross Oversize (mg)		30.1	8507.1	0.0	1.4	140.5	2710.4	5837.7	5.5	99.1	208.2	22.3	4.4	63.6	998.3
Bulk Concentration (mg/kg)		---	---	---	---	---	---	---	---	---	---	---	---	---	<0.8
Total Concentration of Metals Removed on a Weight Basis (mg/kg)	Total Mass of Oversize (kg) 22.2	1.361	383.9	0.0014	0.0614	6.3	122	263	0.2480	4.5	9.4	1.01	0.20	2.9	45
Background Concentration (mg/kg)	Reference 1	<1.0	9910	0.65	0.5	9.8	18.4	27620	<0.1	396.2	7.6	5.08	<10	50.2	NA
	Reference 2	1.53	3070	0.25	0.59	5	10.7	11300	0.049	189	3.8	1.55	5.01	11.5	0
	Reference 3														1.8
Test Performance Criteria (mg/kg)		960	NA	172	320	1600	11840	NA	96	64000	6400	4480	128	64000	155
Concentration of Metals Removed as Percentage of Performance Criteria		0.14	NA	<0.01	0.02	0.40	1.03	NA	0.25	<0.01	0.15	0.02	0.16	<0.01	29

Reference 1 Background Levels are values used for risk calculations from Phase I RI report (DOE-RL 1993c)

Reference 2 Background Levels are taken from Dennison et al (1989)

Reference 3 Uranium Background values taken from internal WHC communication from Scott W. Petersen to Roberta Day, Subject Preliminary Radionuclide Background in Soils

Table 3-6. Pretest Fraction Analysis.

Particle Size Fraction (mm)	PREPROCESSING FEED					PROCESSED FEED				
	Particle Distribution (%)	Copper (mg/kg)	Copper Mass Distribution (%)	Uranium (pCi/g) ^B	Uranium Mass Distribution (%)	Particle Distribution (%)	Copper (mg/kg)	Copper Mass Distribution (%)	Uranium (pCi/g)	Uranium Mass Distribution (%)
37.5-50	12.8	<75	4.2	<8.3	11.0	16.5	<75	5.3	<8.3	14.6
25-37.5	11.9	<75	3.9	<8.3	10.2	17.4	<75	5.6	<8.3	15.4
12.5-25	18	150	23.7	<8.3	15.4	16.9	<75	5.5	<8.3	14.9
4.75-12.5	20.2	<75	6.7	<8.3	17.3	16.9	79	11.5	<8.3	14.9
2.0-4.75	10	<75	3.3	<8.3	8.6	10.7	87	8.0	<8.3	9.4
0.425-2.0	18.3	111	17.9	<8.3	15.7	13.6	149	17.5	<8.3	12.0
0.25-0.425	2	178	3.1	<8.3	1.7	1.9	139	2.3	<8.3	1.7
0.15-0.25	1	352	3.1	<8.3	0.9	0.9	439	3.4	<8.3	0.8
0.075-0.15	0.7	408	2.5	<8.3	0.6	0.8	547	3.8	<8.3	0.7
0.045-0.075	0.5	514	2.3	9	0.9	0.5	727	3.1	9	1.0
<0.0425	4.6	725	29.3	19	17.7	4	983	33.9	17	14.7
Calculated Bulk Concentration		113.8	100	4.9	100		115.9	100	4.7	100

Particle Size Fraction (mm)	OVERSIZE					PRE-TEST 1 SAND				
	Particle Distribution (%)	Copper (mg/kg)	Copper Mass Distribution (%)	Uranium (pCi/g)	Uranium Mass Distribution (%)	Particle Distribution (%)	Copper (mg/kg)	Copper Mass Distribution (%)	Uranium (pCi/g)	Uranium Mass Distribution (%)
37.5-50	1.1	<75	1.0	<8.3	1.1	NS	NS		NS	
25-37.5	7.7	<75	7.3	<8.3	7.7	NS	NS		NS	
12.5-25	22	<75	20.8	<8.3	22.0	NS	NS		NS	
4.75-12.5	46	<75	43.4	<8.3	46.0	NS	NS		NS	
2.0-4.75	21	<75	19.8	<8.3	21.0	0.4	87	0.3	<8.3	0.4
0.425-2.0	2.1	92	4.9	<8.3	2.1	79.4	87 ^A	54.8	<8.3 ^A	75.7
0.25-0.425	0.2	563	2.8	<8.3	0.2	10.1	110	8.8	<8.3	9.6
0.15-0.25	NS	NS		NS		4.7	304	11.3	<8.3	4.5
0.075-0.15	NS	NS		NS		2.8	406	9.0	<8.3	2.7
0.045-0.075	NS	NS		NS		0.9	388	2.8	<8.3	0.9
<0.0425	NS	NS		NS		1.6	1027	13.0	17	6.3
Calculated Bulk Concentration		39.7	100	4.2	100		126.1	100	4.4	100

Note:

^A Insufficient sample was available for sample preprocessing. The value reported is the concentration reported for the 0.425 - 2.0 mm fraction and likely represents a high estimate of the concentration of material present in the fraction and has been included for calculation purposes only.

^B Results for Total Uranium and Uranium-238 are converted between micrograms or milligrams to pCi using the following formula.

Total Uranium (ug/L or mg/kg) = Uranium-238 (pCi/L or pCi/g) x 3.

Table 3-7. Comparison of Preprocessing Feed Composite Samples to the Average Feed Composite for Each Run.

Sample Identification	Concentration in milligrams per kilogram (mg/kg)													
	Silver	Aluminum	Beryllium	Cadmium	Chromium	Copper	Iron	Mercury	Manganese	Nickel	Lead	Antimony	Zinc	Total Uranium
VERIFICATION RUN														
Feed Composite Sample HPFSL-V	<0.58	3630	0.23	<0.30	45.8	127	33600	0.13	388	26	2.9	6.4	29.4	3.8
Feed Soil Average	2.3	5702	0.82	<0.26	50.2	145	40189	0.05	466	28.7	3.5	11.4	51.5	4.3
Standard Dev	0.5	1098	0.14	NA	11	36	8116	0.03	84	5.3	0.8	2.5	8.1	1.4
REPLICATION RUN														
Feed Composite Sample HPFSL-R	<0.58	3320	0.21	<0.29	16.7	61.6	18400	0.08	226	12	2.6	7.4	26.8	3
Feed Soil Average	1.3	3749	0.31	0.71	12.4	79.3	18540	0.07	242	12.8	3	3.2	30.6	3.6
Standard Dev	0.4	585	0.05	0.15	3.3	35.2	2311	0.03	40	3.6	0.6	1.5	4.9	1.1
URANIUM CARBONATE RUN														
Feed Composite Sample HPFSL-G	26	8860	0.35	0.79	144	2260	29700	1.8	327	182	13.1	7.8	64.4	340
Feed Soil Average	23.8	10834	0.33	1.16	177	2768	31900	2.2	357	223	19.9	9.5	83.4	397
Standard Dev	7.3	2803.4	0.11	0.46	50	1102	4199	0.5	31	77	6.3	1.2	29.5	145

Table 3-8. Particle Size Distribution Analysis Results for Process Products, Pretest Run.

Size Fraction (mm)	Particle Size Distribution (%)				
	FEED	OVERSIZE PRODUCT		SAND PRODUCT	
	Pre-Test 1&2 Feed Composite	Pre-Test 1	Pre-Test 2	Pre-Test 1	Pre-Test 2
(+37.5-50)	16.5	1.1 ^A	---	---	---
(25-37.5)	17.4	7.7 ^A	---	---	---
(12.5-25)	16.9	22.0 ^A	---	---	---
(4.75-12.5)	16.9	46.0 ^A	---	---	---
(2.0-4.75)	10.7	21.0 ^A	---	0.4	0.2
(0.425-2.0)	13.6	2.1 ^A	---	79.4	81.8
(0.25-0.425)	1.9	0.2 ^A	---	10.1	12.3
(0.15-0.25)	0.9	---	---	4.7	3.5
(0.075-0.15)	0.8	---	---	2.8	0.9
(0.045-0.075)	0.5	---	---	0.9	0.2
(<0.045)	4.0	---	---	1.6	1.2
Total	100	100		100	100

^A Data not representative. Sample was obtained from segregated oversize pile. Sampling method was changed to direct collection of this product from the wet screen discharge end.

Table 3-9. Calculation of Hydrocyclone Separation Efficiency for Pretest Run.

Size fraction (mm)	Calculated Size Distribution (%)			Normalized Size Distribution ^A			Hydrocyclone Separation Efficiency (%) ^B	
	FEED	SAND PRODUCT		FEED	SAND PRODUCT			
	Pre-Test 1 & 2	Pre-Test 1	Pre-Test 2	Pre-Test 1 & 2	Pre-Test 1	Pre-Test 2	Pre-Test 1	Pre-Test 2
(0.25-2.0)	71.4	89.9	94.2	100.0	100.0	100.0	100	100
(0.15-0.25)	4.1	4.7	3.5	5.8	5.3	3.7	90	64
(0.075-0.15)	3.7	2.8	0.9	5.2	3.1	1.0	61	19
(0.045-0.075)	2.3	0.9	0.2	3.2	1.0	0.2	31	7
(<0.045)	18.4	1.6	1.2	25.8	1.8	1.3	7	5
Total	100.0	100.0	100.0	140.0	111.2	106.2	79	76

^AThe recovery efficiency of the hydrocyclone underflow (sand) for the 0.25 mm to 2.0 mm fraction was set at 100% because no material greater than 0.25 mm was detected in the hydrocyclone overflow (fines). The relative masses for the other fraction monitored (compared to the 0.25 to 2 mm which was measured at 100%) are calculated using the following formula:

$$RM (\%) = [(Frac X / Frac 0.25 \text{ to } 2.0) \times 100]$$

^BThe Hydrocyclone Separation Efficiency is a numerical expression of the efficiency of the particular hydrocyclone to separate a particular size particle from the influent and carry it with the underflow (sand fraction). The efficiency is a ratio of the relative mass of particles present in the underflow divided by the relative mass of the same size particles present in the feed material. The Hydrocyclone Separation Efficiency is calculated using the following formula:

$$Rec \text{ Eff } (\%) = [(\% \text{ Frac } X_{\text{sand}} / \% \text{ Frac } 0.25 \text{ to } 2.0_{\text{sand}}) / (\% \text{ Frac } X_{\text{feed}} / \% \text{ Frac } 0.25 \text{ to } 2.0_{\text{feed}})] \times 100$$

$$31\% = [(0.9/89.9)/(2.3/71.4)]$$

Where Rec Eff = recovery efficiency of the hydrocyclone underflow

% Frac X = % distribution of the fraction in question in either the sand or feed material, as appropriate

% Frac 0.25 to 2.0 = % distribution of the fraction from 0.25 mm to 2.0 mm in either the sand or feed material, as appropriate

Table 3-10. Results of the Field XRF Analyses of the Feed Material and Plant Products Generated During Pretest¹.

	Copper (mg/kg)	Uranium (mg/kg)	Uranium-238 ^A (pCi/g)		Copper (mg/kg)	Uranium (mg/kg)	Uranium-238 ^A (pCi/g)
FEED MATERIAL				PROCESS OVERSIZE			
HPFSL-001	108	<25	<8.3	HPOSL-001	<75	<25	<8.3
HPFSL-002	159	<25	<8.3	HPOSL-002	<75	<25	<8.3
Average	134	<25	<8.3	Average	<75	<25	<8.3
CLEAN SAND				FINES			
HPCSL-001	191	<25	<8.3	HPDSL-001	865	48	16
HPCSL-002	215	<25	<8.3	HPDSL-002	926	49	16
HPCSL-003	96	<25	<8.3	HPDSL-003	906	35	12
HPCSL-004	158	<25	<8.3	HPDSL-004	659	29	10
Average	165	<25	<8.3	Average	839	40	13

^A Results for Total Uranium and Uranium-238 are converted between ug/L or mg/kg to pCi/g using the following formula.

Total Uranium (ug/L or mg/kg) = Uranium-238 (pCi/L or pCi/g) x 3.

Table 3-11. Results of the Confirmation Analysis of Feed Material, Plant Products, and Field Standards Conducted by PNL, Pretest Run.

Sample Identification	Concentration in milligrams per kilogram (mg/kg)													
	Silver	Aluminum	Beryllium	Cadmium	Chromium	Copper	Iron	Mercury	Manganese	Nickel	Lead	Antimony	Zinc	Total Uranium
PRE-TEST RUN														
Feed Sample HPFSL-001	<33	68700	NA	<37	29	201	72500	<8.5	1129	31.6	8.1	<48	90	50.5
Process Oversize Sample HPOS-001	<35	65800	NA	<41	36	75.2	77000	<8.3	1230	<15	7.6	<54	96.6	10.1
Fines Sample HPDSL-001	<43	82300	NA	<44	69	886	58700	<7.7	1350	109	69.2	<58	137	41.2
Field Standard 500 ppm Cu, Cr and U (HPGSL-BKG-5)	<37	68600	NA	<41	655	510	71900	<8.4	1268	<15	17.6	<53	84.8	505
Test Performance Criteria (mg/kg)	960	NA	172	320	1600	11840	NA	96	64000	6400	4480	128	64000	150

Table 3-12. Process Product Mass Balance for Verification Run
(Excluding Material > 50 mm).

	Mass (tons)	% Solids (%)	Mass (dry) (tons)	Distribution by Dry Weight (%) ^A
Plant Feed (< 50 mm)	79.8	96.5	77.0	
Oversize Product (2.0 - 50 mm)	62.9	95.0 ^B	59.8	76.8
Sand Product (0.075 - 2.0 mm)	16.0	88.0 ^B	14.1	18.1
Sludge Product (< 0.075 mm)	6.3	62.7	4.0	5.1
Total	85.2		77.9	100
		Recovery (%) ^C	101.1	

^A Distribution calculated based on particle size analysis of feed material

^B Estimated percentage of dry solids at time of weighing

^C Recovery defined as total dry mass of recovered products as a percentage of feed weight

Table 3-13. Particle Size Distribution Analysis for Soil Fractions, Verification Run.

Sieve Size (mm)	Fraction (mm)	SIZE DISTRIBUTION (%)							
		Feed		Oversize		Sand		Sludge	
		Sampling Event Initial	Sampling Event Final	Sampling Event Initial	Sampling Event Final	Sampling Event Initial	Sampling Event Final	Sampling Event Initial	Sampling Event Final
37.5	(+37.5-50)	6.6	9.8	13.7	22.2	—	—	—	—
25	(25-37.5)	14.2	10.2	25.5	27.4	—	—	—	—
12.5	(12.5-25)	22.7	19.8	25.8	28.4	—	—	—	—
4.75	(4.75-12.5)	19.8	18.9	23.3	15.2	—	—	—	—
2	(2.0-4.75)	11.7	11.7	11.3	6.2	0.2	0.4	—	—
0.425	(0.425-2.0)	15.5	19	0.3	0.5	76.4	82.7	—	—
0.25	(0.25-0.425)	2.5	2.5	0.1	0.1	12.1	9.5	—	—
0.15	(0.15-0.25)	1.1	1	—	—	4.6	3.6	2.3	0.1
0.075	(0.075-0.15)	0.8	0.9	—	—	3.4	2.1	5.7	1.7
0.045	(0.045-0.075)	0.5	0.5	—	—	1.5	0.4	13.8	6.9
<0.045	(<0.045)	4.5	5.7	—	—	1.8	1.2	78.1	91.2
TOTAL		100	100	100	100	100	100	100	100
Separation Efficiency (%) ^A				99.6	99.4	96.5	97.9	91.9	98.1

Bold indicates fractions that should be in process product.

^A Separation Efficiency is defined as the size fractions that should be in process product as a percentage of total material in process product.

Table 3-14. Soil Feed Particle Size Distribution of Original Soil, Verification Run.

Fraction (mm)	DISTRIBUTION (%)		
	Sampling Event		Average
	Initial	Final	
(> 50)	27.3	27.3	27.3
(37.5-50)	4.8	7.1	6.0
(25-37.5)	10.3	7.4	8.8
(12.5-25)	16.3	14.4	15.4
(4.75-12.5)	14.4	13.7	14.0
(2.0-4.75)	8.5	8.5	8.5
(0.425-2.0)	11.3	13.8	12.6
(0.25-0.425)	1.8	1.8	1.8
(0.15-0.25)	0.8	0.7	0.8
(0.075-0.15)	0.6	0.7	0.6
(0.045-0.075)	0.4	0.4	0.4
(<0.045)	3.3	4.1	3.7
Total	100	100	100

Table 3-15. Results of the Chemical and Radiochemical Analysis of Soils and Water Conducted During the Verification Run. (sheet 1 of 4)

Sample Identification	Silver	Aluminum	Beryllium	Cadmium	Chromium	Copper	Iron	Mercury	Manganese	Nickel	Lead	Antimony	Zinc	Total Uranium ^A
FEED SOIL (mg/kg)														
HVFSL-001	1.8	4530	0.79	<0.27 U/J	40.3	102 J	35100	<0.05 U/J	407	23.0	3.1 J	10.4	53.8	2.4
HVFSL-002	2.7	6690	0.92	<0.26 U/J	50.4	165 J	41800	0.08 J	486	31.2	3.7 J	12.5	52.2	4.2
HVFSL-003	2.2	4580	0.68	<0.25 U/J	38.2	128 J	31900	0.06 J	371	23.5	3.0 J	8.2	41.9	4.5
HVFSL-004	2.4	5120	0.76	<0.27 U/J	39.6	161 J	34400	0.11 J	421	26.9	4.2 J	11.0	49.6	5.0
HVFSL-005	2.8	7680	1.1	<0.25 U/J	69.4	189 J	57800	<0.05 U/J	638	38.0	3.8 J	16.1	69.0	5.0
HVFSL-006	3.0	6420	0.87	<0.26 U/J	52.7	202 J	40400	0.06 J	476	32.8	4.0 J	11.9	53.4	4.8
HVFSL-007	1.8	5310	0.74	<0.25 U/J	52.6	113 J	37800	<0.05 U/J	448	26.4	4.6 J	11.0	44.4	4.4
HVFSL-008	2.1	6210	0.87	<0.26 U/J	64.3	138 J	47500	<0.04 U/J	546	32.8	2.4 J	13.4	55.0	6.6
HVFSL-009	1.8	4780	0.66	<0.25 U/J	44.7	108 J	35000	<0.05 U/J	398	23.5	2.3 J	8.4	44.3	2.2
Average	2.3	5702	0.82	<0.26	50.2	145	40189	0.05	466	28.7	3.5	11.4	51.5	4.3
Standard Dev	0.5	1098	0.14	NA	11.0	36	8116	0.03	84	5.3	0.8	2.5	8.1	1.4
%RSD	20.2	19.2	16.6	NA	21.8	24.9	20.2	69.7	18.0	18.3	23.2	21.4	15.7	31.1
PROCESS OVERSIZE (mg/kg)														
HVOSL-001	0.92	3640	0.75	<0.26 U/J	43.2 J	62.6 J	34900 J	<0.051	380 J	22.4 J	1.1	10.5	39.8 J	0.6 J
HVOSL-002	0.40	2850	0.53	<0.25 U/J	17.3 J	33.9 J	22800 J	<0.051	293 J	13.0 J	1.3	6.0	30.2 J	2.0
HVOSL-003	0.50	2650	0.57	<0.26 U/J	12.0 J	29.6 J	19000 J	<0.051	229 J	9.1 J	2.2	6.2	29.9 J	1.7
HVOSL-004	<0.41	3600	0.62	<0.26 U/J	14.4 J	41.9 J	24500 J	<0.051	266 J	11.1 J	1.8	7.4	36.1 J	<1.3
HVOSL-005	0.42	2510	0.53	<0.24 U/J	11.8 J	26.4 J	18800 J	<0.051	202 J	8.0 J	1.3	5.9	30.1 J	<2.0
HVOSL-006	<0.41	2610	0.36	<0.26 U/J	11.5 J	32.1 J	16000 J	<0.051	176 J	9.5 J	1.3	4.4	24.5 J	2.4
HVOSL-007	0.46	3060	0.53	<0.26 U/J	17.7 J	36.2 J	21200 J	<0.051	220 J	11.3 J	1.5	6.6	28.5 J	<1.7
HVOSL-008	0.56	3240	0.64	<0.25 U/J	16.6 J	36 J	24300 J	<0.051	263 J	10.6 J	1.4	8.4	33.3 J	<1.7
HVOSL-009	0.45	2690	0.59	<0.25 U/J	14.7 J	31.3 J	21200 J	<0.052	224 J	9.4 J	1.3	6.3	31.3 J	0.5 J
Average	0.5	2983	0.57	<0.25	17.7	37	22522	<0.051	250	11.6	1.5	6.9	31.5	1.1
Standard Dev	0.2	427	0.11	NA	9.9	11	5393	NA	60	4.3	0.3	1.7	4.4	0.7
%RSD	46.2	14.3	18.5	NA	55.7	29.1	23.9	NA	24.0	37.1	22.9	25.5	14.1	61.4
CLEAN SAND (mg/kg)														
HVCSL-001	1.6	4300	0.77	<0.31	10.2	120	23900	<0.059	288	14.2	4.1	9.1 U	46.2	3.9 J
HVCSL-002	1.5	3870	0.62	<0.31	10.2	117	22000	<0.061	270	16.4	4.5	9.3 U	42.1	5.9
HVCSL-003	1.3	3700	0.66	<0.26	8.7	118	22600	<0.051	280	14.0	3.3	8.2 U	44.2	4.8
HVCSL-004	1.8	4140	0.66	<0.26	11.5	150	23800	<0.051	298	18.1	5.0	10.9 U	43.9	4.6
HVCSL-005	1.8	3880	0.76	<0.27	8.4	103	24700	<0.051	310	13.2	3.6	12.1 U	47.9	4.1
HVCSL-006	1.9	3690	0.65	<0.26	11.2	131	23700	<0.051	285	14.6	4.2	10.8 U	46.4	5.2
HVCSL-007	1.3	3400	0.65	<0.26	7.0	111	21500	<0.051	248	12.2	3.2	10 U	43.8	3.4
HVCSL-008	1.3	3770	0.76	<0.25	9.2	93.5	24800	<0.051	314	13.1	3.3	10.4 U	48.1	4
HVCSL-009	1.5	3860	0.83	<0.26	10.5	107	25800	<0.051	306	12.7	3.5	6.7 U	73.3	3.6 J
Average	1.6	3846	0.71	<0.27	9.7	117	23644	<0.053	289	14.3	3.9	9.7	48.4	4.4
Standard Dev	0.2	261	0.07	NA	1.5	17	1396	NA	21	1.9	0.6	1.6	9.5	0.8
%RSD	15.1	6.8	10.4	NA	15.0	14.1	5.9	NA	7.3	13.3	16.3	16.6	19.7	18.4

Table 3-15. Results of the Chemical and Radiochemical Analysis of Soils and Water Conducted During the Verification Run. (sheet 2 of 4)

Identification	Silver	Aluminum	Beryllium	Cadmium	Chromium	Copper	Iron	Mercury	Manganese	Nickel	Lead	Antimony	Zinc	Total Uranium ^a
FINES (mg/kg)														
HVDSL-001	19.9 J	25900	0.12	1.2	64.4 J	1070	36300	2.2 J	947	106 J	46.0 J	<6.0	128 J	36 J
HVDSL-002	18.9 J	25900	0.54	0.95	61.8 J	1020	35500	1.5 J	958	101 J	54.6 J	<5.7	127 J	51
HVDSL-003	17.5 J	22400	0.48	1.3	56.1 J	941	32100	1.1 J	905	93.0 J	34.2 J	<6.8	101 J	53
HVDSL-004	15.8 J	22800	0.65	0.95	52.4 J	857	31100	1.4 J	846	85.0 J	32.3 J	<7.8	97.8 J	70
HVDSL-005	17.8 J	24800	0.50	0.91	58.1 J	954	34300	1.2 J	935	95.7 J	35.3 J	<7.0	104 J	55
HVDSL-006	20.9 J	31400	0.45	1.6	69.4 J	1130	42100	1.5 J	1130	115 J	38.7 J	<7.6	125 J	58
HVDSL-007	17.1 J	21300	0.65	1.1	53.9 J	924	31300	1.2 J	906	90.3 J	28.4 J	<7.9	99.1 J	71
HVDSL-008	18.6 J	25000	0.51	1.0	59.7 J	988	35800	1.3 J	997	97.4 J	31.8 J	<7.2	110 J	66
HVDSL-009	16.3 J	22400	0.54	<0.78	52.1 J	866	32100	1.2 J	880	86.2 J	27.6 J	<7.6	98.8 J	33 J
Average	18.1	24656	0.49	1.0	58.7	972	34511	1.4	945	96.6	36.5	<7.0	110.1	54.8
Standard Dev	1.7	3033	0.16	0.3	5.8	90	3483	0.3	82	9.6	8.8	NA	13.0	13.6
%RSD	9.2	12.3	31.7	31.5	9.9	9.3	10.1	23.7	8.7	10.0	24.0	NA	11.8	24.8
MAKEUP WATER (ug/L)														
HPMWA-001	<4.1	<16.3	<0.3	<2.6	<3.3	6.2	403	<0.1	16.7	<9.2	<1.0 U/J	<25.4	9.0 U/J	4.2
HPMWA-002	<4.1	<16.3	<0.3	<2.6	<3.3	<3.3	236	<0.1	9.6	<9.2	<1.0 U/J	<25.4	10.4 U/J	5.1
Average	<4.1	<16.3	<0.3	<2.6	<3.3	3.9	320	<0.1	13.2	<9.2	<1.0	<25.4	9.7	4.7
RECYCLED PROCESS WATER (ug/L)														
HVRWA-001 ^B	68.4 J	58300 J	5.5	<2.6	205 J	6940 J	14600 J	10.2	4890 J	601 J	68 J	<25.4 R	401 J	540
HVRWA-002 ^B	53.3 J	104000 J	9.9	5.1	347 J	13600 J	12400 J	20.1	8570 J	1190 J	134 J	<25.4 R	755 J	740
HVRWA-003 ^B	63 J	114000 J	13.5	9.2	301 J	20700 J	2670 J	36.1	11200 J	1750 J	57 J	<25.4 R	908 J	1400
HVRWA-004	<4.1 R	522 J	0.70	<2.6	<3.3 U/J	79.2 J	506 J	<0.10	23.3 U/J	<9.2 U/J	1.6 J	<25.4 R	45.3 U/J	160
HVRWA-005	<4.1 R	1030 J	0.70	<2.6	<3.3 U/J	112 J	992 J	<0.10	47.9 J	<9.2 U/J	0.4 U/J	<25.4 R	25.8 U/J	110
HVRWA-006	<4.1 R	863 J	0.70	<2.6	<3.3 U/J	117 J	856 J	<0.10	35.3 J	<9.2 U/J	1.8 J	<25.4 R	29.4 U/J	79
HVRWA-007	<4.1 R	893 J	0.70	<2.6	<3.3 U/J	126 J	900 J	<0.10	38.3 J	<9.2 U/J	2.4 J	<25.4 R	38.7 U/J	97
HVRWA-008	<4.1 R	3230 J	1.0	<2.6	9.1 J	239 J	3210 J	0.14	154 J	15.5 J	5.0 J	<25.4 R	52.2 U/J	100
HVRWA-009	<4.1 R	1270 J	0.70	<2.6	6.7 J	84.5 J	1710 J	<0.10	73.7 J	<9.2 U/J	61 J	<25.4 R	97.7 U/J	16
Average	<4.1	1301	0.8	<2.6	3.7	126	1362	<0.10	62.1	<9.2	12	<25.4	48.2	93.7
Standard Dev	NA	976	0.1	NA	3.3	58	987	NA	48.1	NA	24	NA	26.2	46.8
%RSD	NA	75.0	16.3	NA	88.8	46.1	72.5	NA	77.5	NA	200	NA	54.3	50.0

Table 3-15. Results of the Chemical and Radiochemical Analysis of Soils and Water Conducted During the Verification Run. (sheet 3 of 4)

Sample Identification	Uranium-235	Uranium-238	Cobalt-60	Cesium-137	Thorium-228	Potassium-40
FEED SOIL (pCi/g)						
HVFSL-001	0.027J	0.79J	0.0486	0.0371	0.463	10.4
HVFSL-002		1.4J				
HVFSL-003		1.5J				
HVFSL-004		1.7J				
HVFSL-005		1.7J				
HVFSL-006		1.6J				
HVFSL-007		1.1J				
HVFSL-008		2.2J				
HVFSL-009	0.038J	0.73J	0.0448	0.0464	0.484	11.3
Average	0.033	1.4	0.0467	0.0418	0.474	10.9
Standard Dev	0.008	0.47	0.0027	0.0066	0.015	0.6
%RSD	23.9	33.4	5.8	15.8	3.1	5.9
PROCESS OVERSIZE (pCi/g)						
HVOSL-001	<0.006J	0.2J	<0.02	<0.03	0.418	8.57
HVOSL-002		0.7				
HVOSL-003		<0.6				
HVOSL-004		<0.4				
HVOSL-005		<0.7				
HVOSL-006		0.8				
HVOSL-007		<0.6				
HVOSL-008		<0.6				
HVOSL-009	0.008J	0.18J	<0.02	<0.02	0.443	10.8
Average	<0.006	0.4	<0.02	<0.02	0.431	9.7
Standard Dev	---	0.2	---	---	0.018	1.6
%RSD	---	61.4	---	---	4.1	16.3
CLEAN SAND (pCi/g)						
HVCSL-001	0.053J	1.3J	0.0641	0.0691	0.469	9.46
HVCSL-002		2				
HVCSL-003		1.6				
HVCSL-004		1.5				
HVCSL-005		1.4				
HVCSL-006		1.7				
HVCSL-007		1.1				
HVCSL-008		1.3				
HVCSL-009	0.049J	1.2J	0.0512	0.0444	0.469	9.26
Average	0.051	1.5	0.0577	0.0568	0.469	9.4
Standard Dev	0.003	0.3	0.0091	0.0175	0.000	0.1
%RSD	5.5	19.2	15.8	30.8	0.0	1.5

Table 3-15. Results of the Chemical and Radiochemical Analysis of Soils and Water Conducted During the Verification Run. (sheet 4 of 4)

Sample Identification	Uranium-235	Uranium-238	Cobalt-60	Cesium-137	Thorium-228	Potassium-40
FINES (pCi/g)						
HVDSL-001	0.78J	12J	0.729	0.271	1.07	18.2
HVDSL-002		17				
HVDSL-003		18				
HVDSL-004		23				
HVDSL-005		18				
HVDSL-006		19				
HVDSL-007		24				
HVDSL-008		22				
HVDSL-009	0.47J	11J	0.707	0.313	1.14	17
Average	0.63	18.2	0.718	0.292	1.11	17.6
Standard Dev	0.22	4.5	0.02	0.03	0.05	0.8
%RSD	35.1	24.8	2.2	10.2	4.5	4.8
MAKEUP WATER (pCi/L)						
HPMWA-001	---	1.4	---	---	---	---
HPMWA-002	---	1.7	---	---	---	---
Average	---	1.6	---	---	---	---
RECYCLED PROCESS WATER (pCi/L)						
HVRWA-001	9.6	180	6.95	6.45	13.4	153
HVRWA-002		247				
HVRWA-003		467				
HVRWA-004		53				
HVRWA-005		37				
HVRWA-006		26				
HVRWA-007		32				
HVRWA-008		33				
HVRWA-009	<0.3	5.2	<3.6	<3.9	<6.7	85
Average	<0.3	31.0	<3.6	<3.9	<6.7	85
Standard Dev	---	15.6	---	---	---	---
%RSD	---	50.2	---	---	---	---

^a Results for Total Uranium and Uranium-238 are converted between micrograms and pCi using the following formula: Total Uranium (ug/L or mg/kg) = Uranium-238 (pCi/L or pCi/g) x 3.0

^b Process water samples contained fines carried over from the sludge settling tank into the process water tank due to the upset of the flocculation process.

Table 3-16. Results of the Chemical and Radiochemical Analysis of Soil Fractions
Generated from the Verification Run Products. (sheet 1 of 2)

Sample Identification	Fraction	Silver	Aluminum	Beryllium	Cadmium	Chromium	Copper	Iron	Mercury	Manganese	Nickel	Lead	Antimony	Zinc	Total Uranium	Uranium as U-238 (pCi/g) ^a
FEED SOIL																
HVF1SL-FRCA	(+37.5-50mm)	1.4	4240	0.44	0.35	50.4	74.4	29800	<0.050	479	22.8	2.6	<2.6	65.3	1.9	0.6
HVF1SL-FRCB	(25-37.5mm)	1.3	5010	0.51	<0.25	40.5	52.6	34500	<0.050	385	18.9	2.6	<2.5	41.2	<0.7	<0.2
HVF1SL-FRCC	(12.5-25mm)	2.1	7580	0.84	0.29	56.2	89	6420	<0.050	695	29.0	1.2	<2.4	70.9	1.8	0.6
HVF1SL-FRCD	(4.75-12.5mm)	1.3	4540	0.49	0.26	25.8	47	32600	<0.050	340	16.4	2.5	2.8	45.1	2.2	0.7
HVF1SL-FRCE	(2.0-4.75mm)	2.0	6340	0.76	0.53	45	97.6	57900	<0.050	522	25.9	7.8	<2.5	66.4	2.9	1.0
HVF1SL-FRCF	(0.425-2.0mm)	1.7	5110	0.57	0.31	14.5	115	33500	<0.050	368	16.7	4.8	<2.4	54.5	2.7	0.9
HVF1SL-FRCG	(0.25-0.425mm)	1.8	5530	0.87	<0.26	8.6	139	25300	0.095	355	17.6	1.7	7.7	52.9	5.3	1.8
HVF1SL-FRCH	(0.15-0.25mm)	2.4	5850	0.78	<0.26	11.7	193	23100	0.13	363	21.4	2.3	5.2	51.8	14	4.7
HVF1SL-FRCI	(0.075-0.15mm)	3.2	6790	0.84	<0.25	15.8	297	24900	0.17	422	27.4	13.0	10.0	59.8	17	5.7
HVF1SL-FRCJ	(0.045-0.075mm)	4.7	8330	0.87	<0.26	21.2	449	24700	0.26	516	40.7	17.9	6.3	73.8	25	8.3
HVF1SL-FRCK	(<0.045)	16.1	21900	1.5	<0.25	59.6	940	32800	1.4	966	94.9	55.2	7.8	125	68	23
HVF2SL-FRCA	(+37.5-50mm)	1.4	2990	0.5	<0.24	30.2	46.6	42400	<0.050	449	16.3	1.1	<2.4	49.9	2.0	0.7
HVF2SL-FRCB	(25-37.5mm)	1.1	4850	0.49	0.25	31.4	46.2	32200	<0.051	348	15.6	0.95	<2.4	40.4	1.9	0.6
HVF2SL-FRCC	(12.5-25mm)	2.0	4770	0.48	<0.26	37.3	54.4	36300	<0.050	388	22.5	1.6	<2.6	48.7	2.6	0.9
HVF2SL-FRCD	(4.75-12.5mm)	1.7	3460	0.39	<0.25	30.3	50.7	29900	<0.051	314	16.7	2.2	<2.5	38.5	2.1	0.7
HVF2SL-FRCE	(2.0-4.75mm)	2.0	3850	0.49	<0.25	28.1	69.8	33800	<0.050	353	16.8	2.3	2.5	45.5	2.1	0.7
HVF2SL-FRCF	(0.425-2.0mm)	1.8	3930	0.83	<0.25	9.2	96	28800	0.069	316	9.8	1.1	9	51.5	4.6	1.5
HVF2SL-FRCG	(0.25-0.425mm)	1.6	4370	0.85	<0.25	7.1	116	24600	0.083	313	13.2	1.6	9.1	52.4	6.8	2.3
HVF2SL-FRCH	(0.15-0.25mm)	1.1	3660	0.27	<0.29	7.1	155	16400	0.094	278	14.7	4.4	6	37.5	13	4.3
HVF2SL-FRCI	(0.075-0.15mm)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
HVF2SL-FRCJ	(0.045-0.075mm)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
HVF2SL-FRCK	(<0.045)	12.6	23000	1.5	<0.28	49.6	760	33000	1.2	918	74	30.3	10.9	118	49	16
PROCESS OVERSIZE																
HVO1SL-FRCA	(+37.5-50mm)	1.2	4010	0.27	<0.24	20.5	31.2	22400	<0.050	264	12.2	1.3	<2.4	29.5	<0.7	<0.2
HVO1SL-FRCB	(25-37.5mm)	1.3	3860	0.37	<0.25	24.6	35.7	22400	<0.050	243	13.2	4.9	<2.4	34.8	1.9	0.6
HVO1SL-FRCC	(12.5-25mm)	1.3	3070	0.36	<0.26	21.4	34.4	23700	<0.051	257	15.6	1.3	<2.5	31.7	<0.9	<0.3
HVO1SL-FRCD	(4.75-12.5mm)	1.6	3900	0.43	<0.26	26.8	49.6	30100	<0.050	320	17.1	1.9	<2.5	39.9	2.9	1.0
HVO1SL-FRCE	(2.0-4.75mm)	1.5	3860	0.87	<0.26	29.7	62.7	33700	<0.050	345	16.8	0.57	11.2	49.5	3.2	1.1
HVO1SL-FRCF	(0.425-2.0mm)	1.9	4560	0.88	<0.26	23.2	139	30300	0.1	332	16.6	30	11.9	73.6	<4.0	<1.3
HVO2SL-FRCA	(+37.5-50mm)	1.7	4040	0.41	<0.25	39.2	60.4	31500	<0.050	335	19.6	1.9	<2.5	42.3	2.0	0.7
HVO2SL-FRCB	(25-37.5mm)	1.5	3430	0.37	<0.26	21.4	33	26800	0.065	306	19.6	2.3	<2.6	38.7	2.6	0.9
HVO2SL-FRCC	(12.5-25mm)	1.9	3960	0.45	<0.25	29.3	50.3	30700	<0.050	366	19.3	1.4	<2.5	41.2	1.8	0.6
HVO2SL-FRCD	(4.75-12.5mm)	1.7	3350	0.39	<0.25	25.2	44.4	27700	<0.051	286	14.2	1.6	<2.5	36.9	3.4	1.1
HVO2SL-FRCE	(2.0-4.75mm)	2.3	3930	0.55	<0.25	36.4	74.9	38900	<0.050	389	20.4	3	<2.4	49.1	<0.9	<0.3
HVO2SL-FRCF	(0.425-2.0mm)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3-16. Results of the Chemical and Radiochemical Analysis of Soil Fractions
Generated from the Verification Run Products. (sheet 2 of 2)

Sample Identification	Fraction	Silver	Aluminum	Beryllium	Cadmium	Chromium	Copper	Iron	Mercury	Manganese	Nickel	Lead	Antimony	Zinc	Total Uranium	Uranium as U-238 (pCi/g) ^a
CLEAN SAND																
HVC1SL-FRCF	(0.425-2.0mm)	2.0	3420	0.45	<0.26	8.6	107	25500	<0.050	286	12.7	6.3	<2.5	47	3.8	1.3
HVC1SL-FRCG	(0.25-0.425mm)	1.4	3960	0.74	<0.26	7.8	109	24000	0.06	284	11.3	2.3	7	49.9	4.2	1.4
HVC1SL-FRCH	(0.15-0.25mm)	1.5	4550	0.74	<0.26	8.3	168	20300	0.1	301	17.6	17	5.6	49	12	4.0
HVC1SL-FRCI	(0.075-0.15mm)	2.5	5240	0.5	<0.26	10.8	294	21200	0.15	374	26.9	8.2	<2.5	55.5	11	3.7
HVC1SL-FRCJ	(0.045-0.075mm)	2.5	4580	0.48	<0.26	11.7	346	24100	0.12	426	28	13.9	<2.5	68.4	12	4.0
HVC1SL-FRCK	(<0.045)	10.9	19400	0.94	0.69	55.2	1460	35600	1.1	907	99.5	287	7.5	235	62	21
HVC2SL-FRCF	(0.425-2.0mm)	2.1	3690	0.47	<0.24	10.4	119	28100	<0.050	323	12.8	3.2	<2.4	47.6	4.0	1.3
HVC2SL-FRCG	(0.25-0.425mm)	1.6	3620	0.42	<0.25	6.1	130	21000	0.092	295	14.3	2.9	<2.4	42.6	7.5	2.5
HVC2SL-FRCH	(0.15-0.25mm)	1.9	3460	0.39	<0.25	5.8	158	18700	0.072	332	14.3	2.7	<2.5	41.2	4.2	1.4
HVC2SL-FRCI	(0.075-0.15mm)	2.3	4470	0.50	<0.25	9.1	242	23700	0.084	431	21.0	6.5	<2.4	55.5	8.2	2.7
HVC2SL-FRCJ	(0.045-0.075mm)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
HVC2SL-FRCK	(<0.045)	8.8	20400.0	1.0	0.95	51.4	1170	36700.0	0.8	990.0	79.4	101.0	9.7	171.0	73	24

^a Results for Total Uranium in milligrams/kilogram have been converted to Uranium as Uranium-238 in pCi/g using the following formula: Total Uranium (mg/kg) = Uranium-238 (pCi/g) x 3.0

Table 3-17. Copper Distribution in Process Products from the Verification Run.

Fraction (mm)	Distribution (%)	FEED			Distribution (%)	OVERSIZE			Distribution (%)	SAND			
		Cu-conc. (mg/kg)	Cu-load (mg/kg)	Cu-load (%)		Cu-conc. (mg/kg)	Cu-load (mg/kg)	Cu-load (%)		Cu-conc. (mg/kg)	Cu-load (mg/kg)	Cu-load (%)	
INITIAL SAMPLING EVENT													
(+37.5-50)	6.6	74.4	4.9	4.0	13.7	31.2	4.3	10.3	---	---	---	---	---
(25-37.5)	14.2	52.6	7.5	6.0	25.5	35.7	9.1	22.0	---	---	---	---	---
(12.5-25)	22.7	89	20.2	16.3	25.8	34.4	8.9	21.4	---	---	---	---	---
(4.75-12.5)	19.8	47	9.3	7.5	23.3	49.6	11.6	27.9	---	---	---	---	---
(2.0-4.75)	11.7	97.6	11.4	9.2	11.3	62.7	7.1	17.1	0.2	107 ^A	0.2	0.1	0.1
(0.425-2.0)	15.5	115	17.8	14.4	0.3	139	0.4	1.0	76.4	107	81.7	56.6	56.6
(0.25-0.425)	2.5	139	3.5	2.8	0.1	139 ^A	0.1	0.3	12.1	109	13.2	9.1	9.1
(0.15-0.25)	1.1	193	2.1	1.7	---	---	---	---	4.6	168	7.7	5.4	5.4
(0.075-0.15)	0.8	297	2.4	1.9	---	---	---	---	3.4	294	10.0	6.9	6.9
(0.045-0.075)	0.5	449	2.2	1.8	---	---	---	---	1.5	346	5.2	3.6	3.6
(<0.045)	4.5	940	42.3	34.2	---	---	---	---	1.8	1460	26.3	18.2	18.2
Calculated Totals	100	---	124	100	100	---	41	100	100	---	144	100	100
Measured Bulk Concentration	---	---	102	---	---	---	63	---	---	---	120	---	---
FINAL SAMPLING EVENT													
(+37.5-50)	9.8	46.6	4.6	4.2	22.2	60.4	13.4	27.4	---	---	---	---	---
(25-37.5)	10.2	46.2	4.7	4.3	27.4	33.0	9.0	18.5	---	---	---	---	---
(12.5-25)	19.8	54.4	10.8	9.9	28.4	50.3	14.3	29.2	---	---	---	---	---
(4.75-12.5)	18.9	50.7	9.6	8.8	15.2	44.4	6.7	13.8	---	---	---	---	---
(2.0-4.75)	11.7	69.8	8.2	7.5	6.2	74.9	4.6	9.5	0.4	119 ^A	0.5	0.3	0.3
(0.425-2.0)	19.0	96	18.2	16.8	0.5	139 ^B	0.7	1.4	82.7	119	98.4	71.6	71.6
(0.25-0.425)	2.5	116	2.9	2.7	0.1	139 ^B	0.1	0.3	9.5	130	12.4	9.0	9.0
(0.15-0.25)	1.0	155	1.6	1.4	---	---	---	---	3.6	158	5.7	4.1	4.1
(0.075-0.15)	0.9	297 ^B	2.7	2.5	---	---	---	---	2.1	242	5.1	3.7	3.7
(0.045-0.075)	0.5	449 ^B	2.2	2.1	---	---	---	---	0.4	346 ^B	1.4	1.0	1.0
(<0.045)	5.7	760	43.3	39.8	---	---	---	---	1.2	1170	14.0	10.2	10.2
Calculated Totals	100	---	109	100	100	---	49	100	100	---	137	100	100
Measured Bulk Concentration	---	---	108	---	---	---	31	---	---	---	107	---	---

^A The sample of this particle size fraction was not analyzed due to insufficient sample mass. The material generated from this fraction was combined with the material from the next larger or smaller particle size fraction, as appropriate, generated from the same sampling event. The results of the analysis of the combined sample shown for calculation purposes.

^B The sample of this particle size fraction was not analyzed due to insufficient sample mass. The material generated from this fraction was combined with the material from the same particle size fraction generated during by particle size analysis of the first sample collected from the run. The concentration of the composite sample is shown for calculation purposes.

Table 3-18. Uranium-238 Distribution in Process Products from the Verification Run.

Fraction (mm)	Distribution (%)	FEED			Distribution (%)	OVERSIZE			Distribution (%)	SAND			
		U238-conc. (pCi/g)	U238-load (pCi/g)	U238-load (%)		U238-conc. (pCi/g)	U238-load (pCi/g)	U238-load (%)		U238-conc. (pCi/g)	U238-load (pCi/g)	U238-load (%)	
INITIAL SAMPLING EVENT													
(+37.5-50)	6.6	0.6	0.04	2.3	13.7	<0.2	0.016	2.8	---	---	---	---	---
(25-37.5)	14.2	<0.2	0.02	0.9	25.5	0.6	0.162	28.6	---	---	---	---	---
(12.5-25)	22.7	0.6	0.14	7.6	25.8	<0.3	0.039	6.9	---	---	---	---	---
(4.75-12.5)	19.8	0.7	0.15	8.1	23.3	1.0	0.225	39.9	---	---	---	---	---
(2.0-4.75)	11.7	1.0	0.11	6.3	11.3	1.1	0.121	21.3	0.2	1.3 ^A	0.00	0.1	0.1
(0.425-2.0)	15.5	0.9	0.14	7.8	0.3	<1.3	0.002	0.4	76.4	1.3	0.97	51.5	51.5
(0.25-0.425)	2.5	1.8	0.04	2.5	0.1	<1.3 ^A	0.001	0.1	12.1	1.4	0.17	9.0	9.0
(0.15-0.25)	1.1	5	0.05	2.9	---	---	---	---	4.6	4.0	0.18	9.8	9.8
(0.075-0.15)	0.8	6	0.05	2.5	---	---	---	---	3.4	3.7	0.12	6.6	6.6
(0.045-0.075)	0.5	8	0.04	2.3	---	---	---	---	1.5	4.0	0.06	3.2	3.2
(<0.045)	4.5	23	1.02	56.8	---	---	---	---	1.8	20.7	0.37	19.8	19.8
Calculated Totals	100	---	1.8	100	100	---	0.56	100	100	---	1.9	100	100
Measured Bulk Concentration	---	---	0.8	---	---	---	0.20	---	---	---	1.3	---	---
FINAL SAMPLING EVENT													
(+37.5-50)	9.8	0.7	0.07	3.4	22.2	<0.7	0.07	11.1	---	---	---	---	---
(25-37.5)	10.2	0.6	0.06	3.3	27.4	0.9	0.24	35.6	---	---	---	---	---
(12.5-25)	19.8	0.9	0.17	8.9	28.4	0.6	0.17	25.5	---	---	---	---	---
(4.75-12.5)	18.9	0.7	0.13	6.9	15.2	1.1	0.17	25.8	---	---	---	---	---
(2.0-4.75)	11.7	0.7	0.08	4.2	6.2	<0.3	0.01	1.4	0.4	1.3 ^A	0.14	7.6	7.6
(0.425-2.0)	19.0	1.5	0.29	15.1	0.5	<1.3 ^B	0.003	0.5	82.7	1.3	1.10	58.0	58.0
(0.25-0.425)	2.5	2.3	0.06	2.9	0.1	<1.3 ^A	0.001	0.1	9.5	2.5	0.24	12.5	12.5
(0.15-0.25)	1.0	4.3	0.04	2.2	---	---	---	---	3.6	1.4	0.05	2.7	2.7
(0.075-0.15)	0.9	5.7 ^B	0.05	2.6	---	---	---	---	2.1	2.7	0.06	3.0	3.0
(0.045-0.075)	0.5	8.3 ^B	0.04	2.2	---	---	---	---	0.4	4.0 ^B	0.02	0.8	0.8
(<0.045)	5.7	16.3	0.93	48.2	---	---	---	---	1.2	24.3	0.29	15.4	15.4
Calculated Totals	100	---	1.9	100	100	---	0.7	100	100	---	1.9	100	100
Measured Bulk Concentration	---	---	0.7	---	---	---	0.9	---	---	---	1.2	---	---

^A The sample of this particle size fraction was not analyzed due to insufficient sample mass. The material generated from this fraction was combined with the material from the next larger or smaller particle size fraction, as appropriate, generated from the same sampling event. The results of the analysis of the combined sample shown for calculation purposes.

^B The sample of this particle size fraction was not analyzed due to insufficient sample mass. The material generated from this fraction was combined with the material from the same particle size fraction generated during by particle size analysis of the first sample collected from the run. The concentration of the composite sample is shown for calculation purposes.

Table 3-19. Results of the Analysis of the Volatile Organic Chemicals and Total Solids in Recycled Water Samples. (sheet 1 of 2)

Sample Identification	Methylene Chloride	1,2-Dichloroethene	Concentrations in micrograms per liter (ug/L) unless noted				Tetrachloroethene	Total Solids (mg/l)
			Chloroform	Bromodichloromethane	Trichloroethene	Dibromochloromethane		
VERIFICATION RUN								
HPMWA-1	<5 U	<5	6	2 J	<5	1 J	<5	
HPMWA-2	<5 U	<5	6	2 J	<5	1 J	<5	
HVRWA-1	<5	<5	<5	<5	<5	<5	<5	8880
HVRWA-2	<5	<5	<5	<5	<5	<5	<5	12700
HVRWA-3	<5	<5	<5	<5	<5	<5	<5	16700
HVRWA-4	<5	<5	<5	<5	<5	<5	<5	364
HVRWA-5	<5	<5	<5	<5	<5	<5	<5	325
HVRWA-6	<5	<5	<5	<5	<5	<5	<5	353
HVRWA-7	<5	<5	<5	<5	<5	<5	<5	385
HVRWA-8	<5	<5	<5	<5	<5	<5	<5	492
HVRWA-9	<5	<5	<5	<5	<5	<5	<5	224
Average	<5	<5	<5	<5	<5	<5	<5	357
REPLICATION RUN								
HRMWA-1	6 U	<5	<5	<5	<5	<5	<5	364
HRRWA-1	<5	<5	0.9 J	<5	<5	<5	<5	422
HRRWA-2	<5	<5	<5	<5	<5	<5	<5	284
HRRWA-3	<5 U	<5	<5	<5	<5	<5	<5	313
HRRWA-4	<5	<5	<5	<5	<5	<5	<5	441
HRRWA-5	11 U	<5	<5	<5	<5	<5	<5	356
HRRWA-6	<5 U	<5	<5	<5	<5	<5	<5	312
HRRWA-7	<5 U	<5	<5	<5	<5	<5	<5	366
HRRWA-8	<5	<5	<5	<5	<5	<5	<5	273
HRRWA-9	<5 U	<5	<5	<5	<5	<5	<5	334
HRRWA-10	<5 U	<5	<5	<5	<5	<5	<5	337
Average	<5	<5	<5	<5	<5	<5	<5	380

Table 3-19. Results of the Analysis of the Volatile Organic Chemicals and Total Solids in Recycled Water Samples. (sheet 2 of 2)

Sample Identification	Methylene Chloride	1,2-Dichloroethene	Concentrations in micrograms per liter (ug/L) unless noted				Tetrachloroethene	Total Solids (mg/l)
			Chloroform	Bromodichloromethane	Trichloroethene	Dibromochloromethane		
URANIUM CARBONATE RUN								
HGMWA-001	6 U	<5	<5	<5	<5	<5	<5	342
HGARWA-001	7 U	<5	<5	<5	<5	<5	<5	377
HGARWA-002	6 U	<5	<5	<5	<5	<5	<5	417
HGARWA-003	<5 U	<5	<5	<5	<5	<5	<5	553
HGARWA-004	<5 U	<5	<5	<5	<5	<5	<5	628
HGARWA-005	7 U	<5	<5	<5	<5	<5	<5	706
HGARWA-006	8 U	<5	<5	<5	<5	<5	<5	673
HGARWA-007	<5 U	<5	<5	<5	<5	<5	<5	652
HGWRWA-001	4 U	<5	<5	<5	<5	<5	<5	597
Average	5 U	<5	<5	<5	<5	<5	<5	572

Table 3-20. Comparison of Calculated Soil Fraction Distribution Based on Feed Particle Size Distribution and Fraction Distribution of Field Test, Verification Run.

Fractions	FRACTION DISTRIBUTION (%), DRY WEIGHT BASIS			
	Original soil		Pre-Screened Soil (Fraction <50 mm)	
	Calculated	Field Test	Calculated	Field Test
Gross Oversize (> 50 mm)	27.3	27.3	---	---
Oversize (2.0 - 50 mm)	52.6	55.8	72.6	76.8
Sand (2.0 - 0.075 mm)	15.8	13.2	21.7	18.1
Fines (< 0.075 mm)	4.1	3.7	5.7	5.1
Total	100	100	100	100

Shading represents that these numbers are based on fraction of gross oversize (>50 mm) as determined from Pre-Screening.

Table 3-21. Total Mass Balance and Volume Reduction by Weight for Verification Run (Including Material > 50 mm).

	Mass (tons)
Total Mass Processed	
Fraction (> 50 mm) ^A	30.0
Plant Feed (< 50 mm)	79.8
TOTAL	109.8 (A)
Total Mass Clean	
Oversize (2.0 - 50 mm)	62.9
Sand (0.075 - 2.0 mm)	16.0
TOTAL	78.9 (C)
Total Mass Contaminated	
Sludge Cake (< 0.075 mm)	6.3 (D)
Secondary Waste ^B	0.0 (Esw)
TOTAL	6.3
PERCENT VOLUME REDUCTION BY WEIGHT (%): $(A-D-Esw)*100/A = 94.3 \%$	

^A Calculated based on pre-screening data

^B No secondary waste was generated as a result of the boiling off of process water.

For complete evaluation of the amount of volume reduction by weight, the total mass of secondary waste consisting of dissolved and suspended solids in the process water after processing was determined to be neglectable for each Run (Section 3.4.3.4).

Table 3-22. Process Product Mass Balance for Replication Run.

	Mass (tons)	% Solids (%)	Mass (dry) (tons)	Distribution by Dry Weight (%) ^A
Plant feed (< 50 mm)	52.1	95.1	49.5	
Oversize product (2.0 - 50 mm)	40.2	95.0 ^B	38.2	75.4
Sand product (0.075 - 2.0 mm)	10.9	88.0 ^B	9.6	18.9
Sludge product (< 0.075 mm)	4.9	58.8	2.9	5.7
Total	56.0		50.7	100
		Recovery (%) ^C	102.3	

^A Distribution calculated based on particle size analysis of feed material

^B Estimated percentage of dry solids at time of weighing

^C Recovery defined as total dry mass of recovered products as a percentage of feed weight

Table 3-23. Particle Size Distribution Analysis for Soil Fractions, Replication Run.

Sieve Size (mm)	Fraction (mm)	SIZE DISTRIBUTION (%)							
		Feed		Oversize		Sand		Sludge	
		Sampling Event Initial	Sampling Event Final	Sampling Event Initial	Sampling Event Final	Sampling Event Initial	Sampling Event Final	Sampling Event Initial	Sampling Event Final
37.5	(+37.5-50)	8.1	0.0	21.6	26.4	—	—	—	—
25	(25-37.5)	11.2	3.2	17.7	26.0	—	—	—	—
12.5	(12.5-25)	25.0	14.9	30.3	27.9	—	—	—	—
4.75	(4.75-12.5)	19.4	15.6	22.4	13.8	—	—	—	—
2	(2.0-4.75)	10.3	17.0	7.6	5.8	0.1	0.2	—	—
0.425	(0.425-2.0)	16.6	33.3	0.3	0.1	86.7	83.2	—	—
0.25	(0.25-0.425)	2.4	4.1	0.0	0.0	8.8	9.1	—	—
0.15	(0.15-0.25)	1.0	1.7	—	—	2.1	4.0	1.0	0.1
0.075	(0.075-0.15)	0.8	1.3	—	—	1.4	2.3	2.6	2.2
0.045	(0.045-0.075)	0.5	0.7	—	—	0.0	0.4	6.4	7.1
<0.045	(<0.045)	4.7	8.2	—	—	0.8	0.8	90.1	90.7
TOTAL		100	100	100	100	100	100	100	100
Separation Efficiency (%) ^A				99.6	99.9	99.0	98.6	96.5	97.8

Bold indicates fractions that should be in process product.

^A Separation Efficiency is defined as the size fractions that should be in process product as a percentage of total material in process product.

Table 3-24. Soil Feed Particle Size Distribution of Original Soil, Replication Run.

Fraction (mm)	DISTRIBUTION (%)		
	Sampling Event		Average
	Initial	Final	
(> 50)	27.3	27.3	27.3
(37.5-50)	5.9	0.0	3.0
(25-37.5)	8.1	2.3	5.2
(12.5-25)	18.2	10.8	14.5
(4.75-12.5)	14.1	11.3	12.7
(2.0-4.75)	7.5	12.4	10.0
(0.425-2.0)	12.1	24.2	18.2
(0.25-0.425)	1.7	3.0	2.4
(0.15-0.25)	0.7	1.2	1.0
(0.075-0.15)	0.6	0.9	0.8
(0.045-0.075)	0.4	0.5	0.5
(<0.045)	3.4	6.0	4.7
Total	100	100	100

Table 3-25. Results of the Chemical and Radiochemical Analysis of Soils and Water Conducted During the Replication Run. (sheet 1 of 4)

Sample Identification	Silver	Aluminum	Beryllium	Cadmium	Chromium	Copper	Iron	Mercury	Manganese	Nickel	Lead	Antimony	Zinc	Total Uranium ^A
FEED SOIL (mg/kg)														
HRFSL-001	2.0	4590	0.41	0.90	15.4	130	22200	0.12	298	16.9	3.5 J	5.3	38.4	3.6 J
HRFSL-002	1.8	3500	0.29	0.73	20.5	143	19400	0.099	253	18.8	2.6 J	3.4	29.1	3.2
HRFSL-003	1.7	4620	0.37	0.79	12.1	106	20300	0.088	283	13.8	3.4 J	4.6	34.9	5.2
HRFSL-004	1.1	3810	0.32	0.94	10.5	49.4	19900	<0.052	260	10.6	2.7 J	3.9	32.7	2.0
HRFSL-005	0.8	2830	0.24	0.55	12.5	49.6	15500	0.072	192	16.8	2.5 J	<2.6	23.5	3.9
HRFSL-006	0.9	3140	0.28	0.55	10.0	53.5	14900	0.060	186	8.6	2.1 J	<2.6	23.6	2.3
HRFSL-007	1.3	4010	0.34	0.83	12.7	83.3	19200	0.078	247	12.3	2.4 J	4.1	32.7	4.0
HRFSL-008	1.2	3750	0.28	0.61	10.7	69.2	17800	0.060	224	10.3	3.9 J	2.7	32.7	4.8
HRFSL-009	1.0	3280	0.29	0.53	10.2	57.2	16500	<0.053	198	9.6	3.6 J	<2.7	25.9	4.7
HRFSL-010	1.1	3960	0.31	0.71	9.6	51.9	19700	<0.052	274	10.2	3.4 J	4	32.3	2.2 J
Average	1.3	3749	0.31	0.71	12.4	79.3	18540	0.07	242	12.8	3.0	3.2	30.6	3.6
Standard Dev	0.4	585	0.05	0.15	3.3	35.2	2311	0.03	40	3.6	0.6	1.5	4.9	1.1
%RSD	31.5	15.6	15.8	21.1	26.8	44.4	12.5	49.6	16.5	28.0	20.4	45.8	16.1	31.9
PROCESS OVERSIZE (mg/kg)														
HROSL-001	0.59	2200	0.40	<0.26	6.5	17.0	12600	<0.050	146 J	5.3	1.5	5.7	38.6 J	0.7 J
HROSL-002	0.86	4030	0.56	<0.26	10.5	25.3	20900	<0.051	260 J	8.4	1.4	9.5	36 J	2.4
HROSL-003	0.63	2610	0.42	<0.26	13.0	26.2	16200	<0.051	186 J	10.7	0.83	7.9	26.7 J	<1.6
HROSL-004	0.57	2370	0.30	<0.25	5.7	17.7	11300	<0.052	150 J	3.8	0.89	5.9	26.6 J	<1.5
HROSL-005	0.64	2750	0.42	<0.25	13.7	29.1	17500	<0.051	185 J	10.9	0.74	5.8	26.2 J	2.2
HROSL-006	0.52	1690	0.28	<0.26	6.2	35.8	10500	<0.051	126 J	4.5	1.3	4.9	16.5 J	1.6
HROSL-007	0.59	2600	0.35	<0.26	13.3	26.1	14900	<0.051	162 J	8.2	2.5	7.0	24.1 J	2.8
HROSL-008	0.61	1870	0.36	<0.26	11.1	23.2	14700	<0.051	156 J	6.5	1.3	6.7	21.6 J	<1.4
HROSL-009	0.59	2120	0.36	<0.27	8.7	23.5	14300	<0.053	174 J	7.8	1.2	5.0	20.1 J	2.5
HROSL-010	0.68	2180	0.36	<0.24	11.8	24.2	15900	<0.051	184 J	7.4	1.4	5.1	23.1 J	0.5 J
Average	0.63	2442	0.38	<0.26	10.1	24.8	14880	<0.051	173	7.4	1.3	6.4	26.0	1.5
Standard Dev	0.09	650	0.08	NA	3.1	5.4	3045	NA	36	2.4	0.5	1.5	6.8	0.9
%RSD	14.7	26.6	20.4	NA	30.6	21.6	20.5	NA	21.0	32.5	38.0	23.1	26.2	60.4
CLEAN SAND (mg/kg)														
HRCSL-001	1.2	4270	0.85	<0.25	18.2	97.1	29800	<0.051	356	16.2	4.0	10.4 U	52.5	3.3 J
HRCSL-002	1.6	4620	0.74	<0.28	21.0	134	27000	<0.054	335	17.3	4.0	11.1 U	53.6	2.0
HRCSL-003	1.5	3330	0.63	<0.25	9.3	88.1	22400	<0.051	289	12.7	4.1	8.9 U	43.5	6.7
HRCSL-004	1.7	4830	0.78	<0.26	16.0	110	29200	<0.051	342	15.7	0.3	12.6 U	54.5	4.5
HRCSL-005	1.2	3470	0.66	<0.26	8.6	85.9	23500	<0.051	279	11.6	2.9	10.1 U	50.9	3.6
HRCSL-006	1.4	3810	0.77	<0.26	10.9	91.8	26300	<0.051	309	12.5	4.6	8.4 U	53.2	4.3
HRCSL-007	1.6	3680	0.66	<0.26	9.3	84.8	24300	<0.051	285	12.5	2.7	7.5 U	51.8	4.6
HRCSL-008	1.2	3410	0.64	<0.26	10.0	90.2	23800	<0.051	280	11.7	4.1	8.8 U	60.7	4.8
HRCSL-009	1.5	3660	0.78	<0.26	11.0	98.2	26300	<0.051	300	12.1	5.2	14.1 U	47.8	4.8
HRCSL-010	1.7	3440	0.69	<0.26	9.9	92.4	24900	<0.051	305	12.0	4.2	10.4 U	45.5	3.6 J
Average	1.46	3852	0.72	<0.26	12.4	97.3	25750	<0.051	308	13.4	3.6	10.2	51.4	4.2
Standard Dev	0.20	535	0.07	NA	4.4	14.8	2436	NA	27	2.1	1.4	2.0	4.9	1.2
%RSD	13.8	13.9	10.3	NA	35.0	15.3	9.5	NA	8.9	15.7	37.9	19.6	9.5	29.1

Table 3-25. Results of the Chemical and Radiochemical Analysis of Soils and Water Conducted During the Replication Run. (sheet 2 of 4)

Sample Identification	Silver	Aluminum	Beryllium	Cadmium	Chromium	Copper	Iron	Mercury	Manganese	Nickel	Lead	Antimony	Zinc	Total Uranium ^a
FINES (mg/kg)														
HRDSL-001	14.9	20600	1.3	<0.73 U/J	50.0	788	31400	1.30	863	80.1	49.4	7.4	137 J	36 J
HRDSL-002	16.1	25700	1.5	<0.78 U/J	58.0	870	37100	1.70	1020	95.0	37.0	9.6	88.1 J	50
HRDSL-003	16.0	24700	1.5	<0.64 U/J	57.6	877	36900	1.20	1020	88.9	20.8	6.9	79.4 J	50
HRDSL-004	14.1	24800	1.4	<0.65 U/J	52.7	774	35900	1.10	942	79.6	20.8	7.6	84.5 J	42
HRDSL-005	13.3	22000	1.3	<0.63 U/J	49.3	732	33500	0.94	892	76.1	20.9	7.1	79.8 J	47
HRDSL-006	9.5	19600	1.1	<0.63 U/J	38.6	527	29700	0.68	765	58.6	15.6	9.9	55.2 J	53
HRDSL-007	10.0	22300	1.2	<0.78 U/J	42.9	573	33800	0.82	863	63.6	20.6	<7.7	74.5 J	44
HRDSL-008	11.0	23500	1.4	<0.90 U/J	44.7	579	35800	0.66	910	64.4	19.5	13.1	101 J	45
HRDSL-009	13.8	30800	1.9	<0.79 U/J	57.2	736	45800	0.80	1170	82.8	19.7	11.1	104 J	48
HRDSL-010	12.8	26900	1.6	<0.68 U/J	50.9	681	40400	1.60	1060	75.2	16.6	8.1	75.1 J	26 J
Average	13.2	24090	1.4	<0.72	50.2	714	36030	1.08	951	76.4	24.1	8.5	87.9	44.1
Standard Dev	2.3	3277	0.2	NA	6.6	122	4587	0.37	118	11.5	10.6	2.6	22.1	8.0
%RSD	17.6	13.6	15.9	NA	13.1	17.2	12.7	34.1	12.4	15.1	44.2	30.3	25.2	18.1
INITIAL RECYCLED WATER QUALITY (ug/L)														
HRMWA-1	<4.1	1940 J	0.3	<2.6	7.5	179	1970 J	<0.10	118	20.9	24.3 J	<25.4	101	220
RECYCLED WATER (ug/L)														
HRRWA-001	<4.1	603 J	0.30	<2.6	<3.3	61.2	594 J	<0.10	18.9	<9.2	3.9 J	<25.4	52.5 U	276
HRRWA-002	<4.1	379 J	0.30	<2.6	5.2	76.1	450 J	<0.10	15.8	15.6	1.9 J	<25.4	41.2 U	220
HRRWA-003	<4.1	1020 J	<0.30	<2.6	4.2	73.4	941 J	<0.10	30.9	14.0	5.7 J	<25.4	41.9 U	140
HRRWA-004	<4.1	5550 J	0.70	<2.6	12.6	170	5560 J	0.14	142	23.4	3.9 J	<25.4	52.2 U	130
HRRWA-005	<4.1	4100 J	0.30	<2.6	7.8	114	4010 J	<0.10	97.0	17.0	4.0 J	<25.4	131	120
HRRWA-006	<4.1	954 J	<0.30	<2.6	<3.3	69.4	906 J	<0.10	19.6	10.4	1.7 J	<25.4	54.3 U	77
HRRWA-007	<4.1	2190 J	0.30	<2.6	5.2	101	2030 J	<0.10	49.2	13.7	29.3 J	<25.4	76.0	76
HRRWA-008	<4.1	355 J	0.30	<2.6	<3.3	54.3	411 J	<0.10	13.9	11.5	0.9 J	<25.4	34.2 U	56
HRRWA-009	<4.1	1060 J	0.30	<2.6	4.9	74.9	989 J	<0.10	28.4	<9.2	3.0 J	<25.4	233	62
HRRWA-010	<4.1	726 J	0.30	<2.6	6.8	65.8	720 J	<0.10	18.9	12.0	2.6 J	<25.4	78.8	63
Average	<4.1	1694	0.31	<2.6	5.2	86	1661	<0.10	43	12.6	5.7	<25.4	79.5	122
Standard Dev	NA	1762	0.15	NA	3.4	35	1746	NA	43	5.6	8.4	NA	60.8	74
%RSD	NA	104.1	48.6	NA	65.5	40.2	105.1	NA	98.2	44.4	147.8	NA	76.5	60.7

Table 3-25. Results of the Chemical and Radiochemical Analysis of Soils and Water Conducted During the Replication Run. (sheet 3 of 4)

Sample Identification	Uranium-235	Uranium-238	Cobalt-60	Cesium-137	Thorium-228	Potassium-40
FEED SOIL (pCi/g)						
HRFSL-001	0.052J	1.2J	0.0467	0.0467	0.477	9.8
HRFSL-002		1.1				
HRFSL-003		1.7				
HRFSL-004		0.7				
HRFSL-005		1.3				
HRFSL-006		0.8				
HRFSL-007		1.3				
HRFSL-008		1.6				
HRFSL-009		1.6				
HRFSL-010	0.029J	0.74J	<0.03	<0.02	0.496	11.1
Average	0.041	1.2	0.0308	0.0284	0.487	10.5
Standard Dev	0.016	0.40	---	---	0.013	0.9
%RSD	40.2	31.9	---	---	2.8	8.8
PROCESS OVERSIZE (pCi/g)						
HROSL-001	0.01J	0.23J	<0.02	<0.02	0.478	10.6
HROSL-002		0.80				
HROSL-003		<0.5				
HROSL-004		<0.5				
HROSL-005		0.73				
HROSL-006		0.53				
HROSL-007		0.93				
HROSL-008		<0.5				
HROSL-009		0.83				
HROSL-010	<0.008J	0.27J	<0.02	<0.02	0.460	10.2
Average	<0.008	0.5	<0.02	<0.02	0.469	10.4
Standard Dev	---	0.3	---	---	0.013	0.3
%RSD	---	60.4	---	---	2.7	2.7
CLEAN SAND (pCi/g)						
HRCSL-001	0.056J	1.1J	<0.04	0.0457	0.500	9.78
HRCSL-002		0.7				
HRCSL-003		2.2				
HRCSL-004		1.5				
HRCSL-005		1.2				
HRCSL-006		1.4				
HRCSL-007		1.5				
HRCSL-008		1.6				
HRCSL-009		1.6				
HRCSL-010	0.051J	1.2J	<0.04	0.0439	0.490	8.89
Average	0.054	1.4	<0.04	0.0448	0.50	9.3
Standard Dev	0.004	0.4	---	0.0013	0.01	0.6
%RSD	6.6	29.1	---	2.8	1.4	6.7

Table 3-25. Results of the Chemical and Radiochemical Analysis of Soils and Water
 Conducted During the Replication Run: (sheet 4 of 4)

Sample Identification	Uranium-235	Uranium-238	Cobalt-60	Cesium-137	Thorium-228	Potassium-40
FINES (pCi/g)						
HRDSL-001	0.56J	12J	0.917	0.349	1.50	20.2
HRDSL-002		17				
HRDSL-003		17				
HRDSL-004		14				
HRDSL-005		16				
HRDSL-006		18				
HRDSL-007		15				
HRDSL-008		15				
HRDSL-009		16				
HRDSL-010	0.41J	8.8J	0.481	0.181	1.14	18.2
Average	0.49	14.7	0.699	0.265	1.32	19.2
Standard Dev	0.11	2.7	0.308	0.119	0.25	1.4
%RSD	21.9	18.1	44.1	44.8	19.3	7.4
INITIAL RECYCLED WATER QUALITY (pCi/L)						
HRMWA-1	---	73	---	---	---	---
RECYCLED WATER (pCi/L)						
HRRWA-001	4.5	94	<3.7	<4.3	<7.4	<82
HRRWA-002		73				
HRRWA-003		47				
HRRWA-004		43				
HRRWA-005		40				
HRRWA-006		26				
HRRWA-007		25				
HRRWA-008		19				
HRRWA-009		21				
HRRWA-010	1.0	21	<3.1	<3.7	<6.1	<84
Average	2.8	41	<3.4	<4.0	<6.8	<83
Standard Dev	2.5	25	---	---	---	---
%RSD	90.0	60.7	---	---	---	---

^A Results for Total Uranium and Uranium-238 are converted between micrograms and pCi using the following formula: Total Uranium (ug/L or mg/kg) = Uranium-238 (pCi/L or pCi/g) x 3.0

Table 3-26. Results of the Chemical and Radiochemical Analysis of Soil Fractions
Generated from the Replication Run Products. (sheet 1 of 2)

Sample Identification	Fraction	Silver	Aluminum	Beryllium	Cadmium	Chromium	Copper	Iron	Mercury	Manganese	Nickel	Lead	Antimony	Zinc	Total Uranium	Uranium as U-238 (pCi/g) ^A
FEED SOIL																
HRF1SL-FRCA	(+37.5-50mm)	1.1	2750	0.78	<0.26	21.4	34.3	27000	0.053	280	11.4	1.1	9.3	38.3	1.3	0.4
HRF1SL-FRCB	(25-37.5mm)	1.2	2870	0.68	<0.26	22.3	37.5	26700	0.053	288	12.7	2.5	10.7	33.7	2.4	0.8
HRF1SL-FRCC	(12.5-25mm)	1.1	2970	0.64	<0.26	24.8	36.1	23700	0.055	269	17.2	1.0	8.1	28.8	2.9	1.0
HRF1SL-FRCD	(4.75-12.5mm)	1.4	3430	0.78	<0.26	28.4	47.5	29800	0.057	316	15.1	1.5	10.3	38.9	1.9	0.6
HRF1SL-FRCE	(2.0-4.75mm)	1.8	5150	1.2	<0.26	36.0	74.6	39700	0.066	419	20.3	<0.079	13.7	54.6	5.1	1.7
HRF1SL-FRCF	(0.425-2.0mm)	<0.57	3250	0.27	<0.29	9.3	87.5	21700	0.071	252	11.5	3.1	5.5	36.4	3.6	1.2
HRF1SL-FRCG	(0.25-0.425mm)	<0.57	3880	0.28	<0.29	7.1	141	17400	0.096	258	13.8	4.6	4.0	37.0	5.2	1.7
HRF1SL-FRCH	(0.15-0.25mm)	0.6	3970	0.29	<0.29	7.8	145	16900	0.10	314	14.6	5.4	4.4	37.5	10	3.3
HRF1SL-FRCI	(0.075-0.15mm)	1.7	4800	0.32	<0.29	11.6	256	17600	0.16	379	22.4	9.4	5.0	45.2	15	5.0
HRF1SL-FRCJ	(0.045-0.075mm)	2.3	6150	0.38	0.35	15.8	355	19900	0.24	487	31.9	11.1	4.5	54.6	26	8.7
HRF1SL-FRCK	(<0.045)	11.1	20000	0.91	0.42	49.0	726	32300	1.2	951	71.8	25.4	<3.3	107	45	15
HRF2SL-FRCA	(+37.5-50mm)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
HRF2SL-FRCB	(25-37.5mm)	1.2	2270	0.3	<0.26	27.2	45.6	23600	<0.051	261	15.0	1.3	<2.52	27.3	3.5	1.2
HRF2SL-FRCC	(12.5-25mm)	1.4	4000	0.38	<0.24	38.3	60.4	30900	0.053	346	19.4	3.1	<2.4	33.5	1.6	0.5
HRF2SL-FRCD	(4.75-12.5mm)	1.3	2640	0.33	<0.25	27.7	48.2	25300	0.062	268	14.9	3.0	<2.4	28.2	1.7	0.6
HRF2SL-FRCE	(2.0-4.75mm)	1.7	2910	0.33	0.25	27.2	64.5	28000	0.061	295	16.0	2.7	<2.4	36.4	2.4	0.8
HRF2SL-FRCF	(0.425-2.0mm)	1.3	2850	0.36	<0.24	10.5	100	21800	0.075	244	11.4	3.5	<2.4	34.2	3.5	1.2
HRF2SL-FRCG	(0.25-0.425mm)	<0.57	3490	0.27	<0.29	5.9	114	16600	0.081	282	11.6	3.9	6.1	34.0	5.6	1.9
HRF2SL-FRCH	(0.15-0.25mm)	0.99	3950	0.29	<0.29	8.1	149	17200	0.12	285	15.1	4.4	4.7	36.8	14	4.7
HRF2SL-FRCI	(0.075-0.15mm)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
HRF2SL-FRCJ	(0.045-0.075mm)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
HRF2SL-FRCK	(<0.045)	10.4	20400	0.94	0.36	47	696	33500	1.1	970	70.1	27	5.9	111	44	15
PROCESS OVERSIZE																
HRO1SL-FRCA	(+37.5-50mm)	1.2	3460	0.81	<0.26	23.0	46.1	28900	0.053	296	13.4	<0.81	12.4	40.0	2.7	0.9
HRO1SL-FRCB	(25-37.5mm)	0.89	3390	0.77	<0.26	27.7	37.1	26500	<0.050	298	15.2	<0.80	7.8	40.8	4.0	1.3
HRO1SL-FRCC	(12.5-25mm)	1.1	3520	0.74	<0.25	26.8	39.5	26700	0.056	290	13.9	<0.76	9.8	35.9	1.8	0.6
HRO1SL-FRCD	(4.75-12.5mm)	<0.61	2770	0.19	0.38	40.5	55.6	30900	0.055	291	19.7	2.1	5.5	27.4	4.7	1.6
HRO1SL-FRCE	(2.0-4.75mm)	<0.57	3130	0.23	<0.29	32.1	56.0	31100	<0.050	298	17.4	2.3	7.3	31.8	2.8	0.9
HRO1SL-FRCF	(0.425-2.0mm)	<0.58	3770	0.27	0.31	17.4	206	20100	0.079	244	15.2	70.8	5.8	84.2	6.3	2.1
HRO2SL-FRCA	(+37.5-50mm)	1.1	1920	0.71	<0.26	25.7	36.6	25300	0.056	274	11.4	<0.78	11.9	28.9	3.2	1.1
HRO2SL-FRCB	(25-37.5mm)	0.66	2690	0.62	<0.25	24.1	32.9	23100	0.055	262	13.0	<0.77	6.5	35.3	2.2	0.7
HRO2SL-FRCC	(12.5-25mm)	1.1	3140	0.64	<0.26	22.8	36.3	22900	0.051	254	14.5	1.3	6.0	31.0	<0.9	<0.3
HRO2SL-FRCD	(4.75-12.5mm)	1.2	3280	0.77	<0.26	49.8	64.1	36300	0.061	375	23.4	1.4	10.3	38.9	2.6	0.9
HRO2SL-FRCE	(2.0-4.75mm)	<0.57	3290	0.25	<0.29	34.8	60.6	34300	<0.050	316	18.8	2.1	9.0	35.5	2.9	1.0
HRO2SL-FRCF	(0.425-2.0mm)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3-26. Results of the Chemical and Radiochemical Analysis of Soil Fractions
Generated from the Replication Run Products. (sheet 2 of 2)

Sample Identification	Fraction	Silver	Aluminum	Beryllium	Cadmium	Chromium	Copper	Iron	Mercury	Manganese	Nickel	Lead	Antimony	Zinc	Total Uranium	Uranium as U-238 (pCi/g) ^a
CLEAN SAND																
HRC1SL-FRCF	(0 425-2 0mm)	<0.57	4770	0.36	<0.29	15.6	88.6	34000	0.069	352	14.0	3.7	9.0	50.8	<1.0	<0.3
HRC1SL-FRCG	(0 25-0 425mm)	<0.57	3470	0.26	<0.29	4.8	101	17000	0.064	234	11.5	16.2	3.7	34.8	6.6	2.2
HRC1SL-FRCH	(0 15-0 25mm)	<0.57	4420	0.30	<0.29	7.1	143	17700	0.083	313	15.4	4.2	<3.3	39.7	12	4.0
HRC1SL-FRCI	(0 075-0 15mm)	<0.57	5070	0.33	<0.29	9.0	196	19000	0.1	359	19.6	12.3	<3.3	47.1	20	6.7
HRC1SL-FRCJ	(0 045-0 075mm)	6.1	17300	0.84	<0.29	39.2	929	37400	0.63	843	68.4	81.9	5.9	154	59	19.7
HVC1SL-FRCK	(<0 045)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
HRC2SL-FRCF	(0 425-2 0mm)	1.9	3170	0.46	<0.24	8.7	93.7	25400	0.059	280	10.3	4.9	<2.4	42.4	3.6	1.2
HRC2SL-FRCG	(0 25-0 425mm)	<0.57	3250	0.25	<0.29	4.7	105	16700	0.064	256	10.9	4.2	<3.3	34.6	5.4	1.8
HRC2SL-FRCH	(0 15-0 25mm)	<0.57	3690	0.28	<0.29	6.4	124	17900	0.069	303	13.4	5.1	5	38.2	5.9	2.0
HRC2SL-FRCI	(0 075-0 15mm)	<0.57	3910	0.29	<0.29	7.1	160	18900	0.09	320	15.0	7.2	5.7	40.8	19	6.3
HRC2SL-FRCJ	(0 045-0 075mm)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
HRC2SL-FRCJ	(<0 045)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

^a Results for Total Uranium in milligrams/kilogram have been converted to Uranium as Uranium-238 in pCi/g using the following formula: Total Uranium (mg/kg) = Uranium-238 (pCi/g) x 3.0

Table 3-27. Copper Distribution in Process Products from the Replication Run.

Fraction (mm)	Distribution (%)	FEED			OVERSIZE				SAND				
		Cu-conc (mg/kg)	Cu-load (mg/kg)	Cu-load (%)	Distribution (%)	Cu-conc. (mg/kg)	Cu-load (mg/kg)	Cu-load (%)	Distribution (%)	Cu-conc. (mg/kg)	Cu-load (mg/kg)	Cu-load (%)	
INITIAL SAMPLING EVENT													
(+37.5-50)	8.1	34.3	2.8	3.1	21.6	46.1	10.0	21.7	---	---	---	---	---
(25-37.5)	11.2	37.5	4.2	4.7	17.7	37.1	6.6	14.3	---	---	---	---	---
(12.5-25)	25.0	36.1	9.0	10.0	30.3	39.5	12.0	26.1	---	---	---	---	---
(4.75-12.5)	19.4	47.5	9.2	10.2	22.4	55.6	12.5	27.2	---	---	---	---	---
(2.0-4.75)	10.3	74.6	7.7	8.5	7.6	56.0	4.3	9.3	0.1	88.6 ^A	0.1	0.1	0.1
(0.425-2.0)	16.6	87.5	14.5	16.1	0.3	206	0.6	1.3	86.7	88.6	76.8	77.6	77.6
(0.25-0.425)	2.4	141	3.4	3.8	0.0	206 ^A	0.0	0.0	8.8	101	8.9	9.0	9.0
(0.15-0.25)	1.0	145	1.5	1.6	---	---	---	---	2.1	143	3.0	3.0	3.0
(0.075-0.15)	0.8	256	2.0	2.3	---	---	---	---	1.4	196	2.7	2.8	2.8
(0.045-0.075)	0.5	355	1.8	2.0	---	---	---	---	0.0	929	0.0	0.0	0.0
(<0.045)	4.7	726	34.1	37.8	---	---	---	---	0.8	929 ^A	7.4	7.5	7.5
Calculated Totals	100		90.2	100.0	100		46	100	100		99	100	100
Measured Bulk Concentration			130.0				17				97		
FINAL SAMPLING EVENT													
(+37.5-50)	0.0	NA			26.4	36.6	9.7	23.6	---	---			
(25-37.5)	3.2	45.6	1.5	1.1	26.0	32.9	8.6	20.9	---	---			
(12.5-25)	14.9	60.4	9.0	6.8	27.9	36.3	10.1	24.8	---	---			
(4.75-12.5)	15.6	48.2	7.5	5.7	13.8	64.1	8.8	21.6	---	---			
(2.0-4.75)	17.0	64.5	11.0	8.3	5.8	60.6	3.5	8.6	0.2	93.7 ^A	0.2	0.2	0.2
(0.425-2.0)	33.3	100	33.3	25.2	0.1	206 ^B	0.2	0.5	83.2	93.7	78.0	72.5	72.5
(0.25-0.425)	4.1	114	4.7	3.5	0.0	206 ^A	0.0	0.0	9.1	105	9.6	8.9	8.9
(0.15-0.25)	1.7	149	2.5	1.9	---	---	---	---	4	124	5.0	4.6	4.6
(0.075-0.15)	1.3	256 ^B	3.3	2.5	---	---	---	---	2.3	160	3.7	3.4	3.4
(0.045-0.075)	0.7	355 ^B	2.5	1.9	---	---	---	---	0.4	929 ^B	3.7	3.5	3.5
(<0.045)	8.2	696	57.1	43.1	---	---	---	---	0.8	929 ^A	7.4	6.9	6.9
Calculated Totals	100		132	100	100		41	100	100		107	100	100
Measured Bulk Concentration			52				24				92		

^A The sample of this particle size fraction was not analyzed due to insufficient sample mass. The material generated from this fraction was combined with the material from the next larger or smaller particle size fraction, as appropriate, generated from the same sampling event. The results of the analysis of the combined sample shown for calculation purposes.

^B The sample of this particle size fraction was not analyzed due to insufficient sample mass. The material generated from this fraction was combined with the material from the same particle size fraction generated during by particle size analysis of the first sample collected from the run. The concentration of the composite sample is shown for calculation purposes.

Table 3-28. Uranium-238 Distribution in Process Products from the Replication Run.

Fraction (mm)	Distribution (%)	FEED			Distribution (%)	OVERSIZE			Distribution (%)	SAND			
		U238-conc (pCi/g)	U238-load (pCi/g)	U238-load (%)		U238-conc. (pCi/g)	U238-load (pCi/g)	U238-load (%)		U238-conc. (pCi/g)	U238-load (pCi/g)	U238-load (%)	
INITIAL SAMPLING EVENT													
(+37.5-50)	8.1	0.4	0.04	2.0	21.6	0.9	0.2	18.7	---				
(25-37.5)	11.2	0.8	0.09	5.2	17.7	1.3	0.2	22.7	---				
(12.5-25)	25.0	1.0	0.24	14.0	30.3	0.6	0.2	17.5	---				
(4.75-12.5)	19.4	0.6	0.12	7.1	22.4	1.6	0.4	33.7	---				
(2.0-4.75)	10.3	1.7	0.18	10.1	7.6	0.9	0.1	6.8	0.1	<0.3 ^A	0.00	0.0	
(0.425-2.0)	16.6	1.2	0.20	11.5	0.3	2.1	0.0	0.6	86.7	<0.3	0.14	21.5	
(0.25-0.425)	2.4	1.7	0.04	2.4	0.0	2.1 ^A	0.0	0.0	8.8	2.2	0.19	28.8	
(0.15-0.25)	1.0	3	0.03	1.9	---				2.1	4.0	0.08	12.5	
(0.075-0.15)	0.8	5	0.04	2.3	---				1.4	6.7	0.09	13.9	
(0.045-0.075)	0.5	9	0.04	2.5	---				0.0	19.7	0.00	0.0	
(<0.045)	4.7	15	0.71	40.8	---				0.8	19.7 ^A	0.16	23.4	
Calculated Totals	100		1.73	100.0	100		1.0	100.0	100		0.7	100	
Measured Bulk Concentration			1.20				0.2				1.1		
FINAL SAMPLING EVENT													
(+37.5-50)	0.0	NA			26.4	1.1	0.28	40.7	---	---			
(25-37.5)	3.2	1.2	0.04	1.7	26.0	0.7	0.19	27.6	---	---			
(12.5-25)	14.9	0.5	0.08	3.6	27.9	<0.3	0.04	6.0	---	---			
(4.75-12.5)	15.6	0.6	0.09	4.0	13.8	0.9	0.12	17.3	---	---			
(2.0-4.75)	17.0	0.8	0.14	6.1	5.8	1.0	0.06	8.1	0.2	1.2 ^A	0.00	0.1	
(0.425-2.0)	33.3	1.2	0.39	17.5	0.1	2.1 ^B	0.00	0.3	83.2	1.2	1.00	61.4	
(0.25-0.425)	4.1	1.9	0.08	3.5	0.0	2.1 ^A	0.00	0.0	9.1	1.8	0.16	10.1	
(0.15-0.25)	1.7	4.7	0.08	3.6	---	---			4.0	2.0	0.08	4.8	
(0.075-0.15)	1.3	5.0 ^B	0.07	2.9	---	---			2.3	6.3	0.15	9.0	
(0.045-0.075)	0.7	8.7 ^B	0.06	2.7	---	---			0.4	19.7 ^B	0.08	4.8	
(<0.045)	8.2	14.7	1.20	54.3	---	---			0.8	19.7 ^A	0.16	9.7	
Calculated Totals	100		2.2	100.0	100		0.7	100	100		1.6	100	
Measured Bulk Concentration			0.7				0.3				1.2		

^A The sample of this particle size fraction was not analyzed due to insufficient sample mass. The material generated from this fraction was combined with the material from the next larger or smaller particle size fraction, as appropriate, generated from the same sampling event. The results of the analysis of the combined sample shown for calculation purposes.

^B The sample of this particle size fraction was not analyzed due to insufficient sample mass. The material generated from this fraction was combined with the material from the same particle size fraction generated during by particle size analysis of the first sample collected from the run. The concentration of the composite sample is shown for calculation purposes.

Table 3-29. Comparison of Calculated Soil Fraction Distribution Based on Feed Particle Size Distribution and Fraction Distribution of Field Test, Replication Run.

Fractions	FRACTION DISTRIBUTION (%), DRY WEIGHT BASIS			
	Original Soil		Pre-screened Soil (fraction <50 mm)	
	Calculated	Field Test	Calculated	Field Test
Gross Oversize (>50 mm)	27.3	27.3	-	-
Oversize (2.0 - 50 mm)	45.3	54.8	62.4	75.4
Sand (2.0 - 0.075 mm)	22.2	13.7	30.6	18.9
Fines (<0.075 mm)	5.2	4.1	7.1	5.7
Total	100	100	100	100

Shading represents that these numbers are based on fraction of gross oversize (>50 mm) as determined from Pre-Screening.

Table 3-30. Total Mass Balance and Volume Reduction by Weight for Replication Run (Including Material > 50 mm).

	Mass (tons)	
Total Mass Processed		
Fraction (> 50 mm) ^A	19.6	
Plant Feed (< 50 mm)	52.1	
TOTAL	71.7	(A)
Total Mass Clean		
Oversize (2.0 - 50 mm)	40.2	
Sand (0.075 - 2.0 mm)	10.9	
TOTAL	51.1	(C)
Total Mass Contaminated		
Sludge cake (< 0.075 mm)	4.9	(D)
Secondary Waste ^B	0.0	(Esw)
TOTAL	4.9	

PERCENT VOLUME REDUCTION BY WEIGHT (%): $(A-D-Esw)*100/A = 93.2 \%$

^A Calculated based on pre-screening data

^B No secondary waste was generated as a result of the boiling off of process water. For complete evaluation of the amount of volume reduction by weight, the total mass of secondary waste consisting of dissolved and suspended solids in the process water after processing was determined to neglectable for each Run (Section 3.4.3.4).

Table 3-31. Process Product Mass Balance for Uranium Carbonate Run.

	Mass (tons)	% Solids (%)	Mass (dry) (tons)	Distribution by Dry Weight (%) ^A
Plant feed (< 50 mm)	43.1	89.6	38.6	
Oversize product (2.0 - 50 mm)	29.6	95.0 ^B	28.1	72.3
Sand Product (0.075 - 2.0 mm)	10.0	88.0 ^B	8.8	22.6
Sludge Product (< 0.075 mm)	4.5	43.5	2.0	5.1
Total	44.1		38.9	100
		Recovery (%) ^C	100.6	

^A Distribution calculated based on particle size analysis of feed material

^B Estimated percentage of dry solids at time of weighing

^C Recovery defined as total dry mass of recovered products as a percentage of feed weight

Table 3-32. Particle Size Distribution Analysis for Soil Fractions, Uranium Carbonate Run.

Sieve Size (mm)	Fraction (mm)	SIZE DISTRIBUTION (%)							
		Feed		Oversize		Sand		Sludge	
		Sampling Event Initial	Sampling Event Final	Sampling Event Initial	Sampling Event Final	Sampling Event Initial	Sampling Event Final	Sampling Event Initial	Sampling Event Final
37.5	(+37.5-50)	8.1	11.0	10.7	32.7	—	—	—	—
25	(25-37.5)	11.3	19.0	21.6	26.4	—	—	—	—
12.5	(12.5-25)	16.4	22.1	30.9	23.5	—	—	—	—
4.75	(4.75-12.5)	14.6	10.9	22.6	11.4	—	—	—	—
2	(2.0-4.75)	9.3	6.3	10.6	5.2	0.1	0.0	—	—
0.85	(0.850-2.0)	10.3	6.8	ND	ND	28.4	29.4	—	—
0.425	(0.425-0.850)	12.5	11.9	3.0	0.6	43.4	48.7	—	—
0.25	(0.25-0.425)	6.7	4.9	0.6	0.2	18.4	17.3	—	—
0.15	(0.15-0.25)	1.7	1.1	—	—	6.2	3.1	1.1	1.5
0.075	(0.075-0.15)	1.1	0.8	—	—	2.2	0.7	4.2	7.5
0.045	(0.045-0.075)	0.7	0.6	—	—	0.4	0.2	10.9	7.0
<0.045	(<0.045)	7.3	4.6	—	—	0.9	0.6	83.8	83.9
TOTAL		100	100	100	100	100	100	100	100
Separation Efficiency (%)				96.4	99.2	98.6	99.2	94.7	90.9

1) Bold indicates fractions that should be in process product.

2) ND : Not Determined

3) **Separation Efficiency** is defined as the size fractions that should be in process product as a percentage of total material in process product.

Table 3-33. Soil Feed Particle Size Distribution of Original Soil, Uranium Carbonate Run.

Fraction (mm)	DISTRIBUTION (%)		
	Sampling Event		Average
	Initial	Final	
(> 50)	17.6	17.6	17.6
(37.5-50)	6.7	9.1	7.9
(25-37.5)	9.3	15.7	12.5
(12.5-25)	13.5	18.2	15.9
(4.75-12.5)	12.0	9.0	10.5
(2.0-4.75)	7.7	5.2	6.5
(0.850-2.0)	8.5	5.6	7.1
(0.425-0.850)	10.3	9.8	10.1
(0.25-0.425)	5.5	4.0	4.8
(0.15-0.25)	1.4	0.9	1.2
(0.075-0.15)	0.9	0.7	0.8
(0.045-0.075)	0.6	0.5	0.6
(<0.045)	6.0	3.8	4.9
Total	100	100	100

Table 3-34. Results of the Chemical and Radiochemical Analysis of Soils and Water Conducted for the Uranium Carbonate Run. (sheet 1 of 4)

Sample Identification	Silver	Aluminum	Beryllium	Cadmium	Chromium	Copper	Iron	Mercury	Manganese	Nickel	Lead	Antimony	Zinc	Total Uranium ^A
ATTRITIONING CYCLE FEED SOIL (mg/kg)														
HGAFFSL-1	21.0	8000	0.29	0.56	110	1680	30900	1.6	326	142	15.3	9.5	61.4	270 J
HGAFFSL-2	19.8	12800	0.43	1.30	204	3480	30200	2.6	353	269	26.1	10.2	89.6	560
HGAFFSL-3	21.0	13900	0.42	1.70	233	4050	27400	2.6	329	314	25.8	8.4	128	530
HGAFFSL-4	36.8	11700	0.36	1.40	198	3060	32300	2.6	376	245	20.1	8.3	85.3	380
HGAFFSL-5	20.6	7770	0.17	0.84	141	1570	38700	1.6	399	144	12.0	11.2	52.5	243 J
Average	23.8	10834.0	0.33	1.16	177	2768	31900	2.2	357	223	19.9	9.5	83.4	397
Standard Dev.	7.3	2803.4	0.11	0.46	50	1102	4199	0.5	31	77	6.3	1.2	29.5	145
%RSD	30.5	25.9	32.1	39.3	28.3	39.8	13.2	24.9	8.7	34.5	31.5	12.9	35.3	36.6
ATTRITIONING CYCLE PROCESS OVERSIZE (mg/kg)														
HGAOSL-1	2.1	3780	0.20	<0.29	36.5	217	24900	0.18	270	29.6	3.3	7.6	34.0	26 J
HGAOSL-2	5.6	3470	0.09	<0.29	30.7	365	18400	0.29	199	32.7	3.5	5.3	26.6	9.5
HGAOSL-3	1.6	3480	0.17	0.37	35.5	161	22600	0.18	270	25.6	2.8	6.4	34.4	20
HGAOSL-4	1.3	3750	0.22	<0.29	39.7	155	26100	0.13	311	35.8	3.3	6.8	32.2	19
HGAOSL-5	1.1	3580	0.20	<0.29	30.6	98.7	23100	0.058	269	19.7	2.3	7.5	27.0	8.1 J
Average	2.3	3612	0.18	<0.29	34.6	199	23020	0.17	264	28.7	3.0	6.7	30.8	16.5
Standard Dev.	1.9	147	0.05	NA	3.9	102	2939	0.08	40	6.3	0.5	0.9	3.8	7.6
%RSD	79.5	4.1	29.1	NA	11.3	51.0	12.8	50.6	15.3	21.9	16.0	13.9	12.3	45.7
WASHING CYCLE CLEAN SAND (mg/kg)														
HGWCSL-1	6.2	5280	0.22	0.36	39.0	1140	18700	0.31	218	114	12.2	5.1	50.6	81 J
HGWCSL-2	8.2	5840	0.27	0.45	51.2	1400	19500	0.30	249	130	11.8	4.8	55.7	99
HGWCSL-3	6.0	5350	0.24	0.33	41.5	1050	22800	0.30	267	105	8.9	6.9	53.0	83
HGWCSL-4	6.0	5930	0.25	0.57	45.2	1130	29400	0.30	322	114	8.9	9.1	60.5	78
Average	6.6	5600	0.25	0.43	44.2	1180	22600	0.30	264	116	10.5	6.5	55.0	85.3
Standard Dev.	1.1	332	0.02	0.11	5.3	152	4868	0.00	44	10	1.8	2.0	4.2	9.4
%RSD	16.2	5.9	8.5	25.2	12.0	12.9	21.5	1.7	16.5	9.0	17.2	30.6	7.7	11.0

Table 3-34. Results of the Chemical and Radiochemical Analysis of Soils and Water Conducted for the Uranium Carbonate Run. (sheet 2 of 4)

Sample Identification	Silver	Aluminum	Beryllium	Cadmium	Chromium	Copper	Iron	Mercury	Manganese	Nickel	Lead	Antimony	Zinc	Total Uranium ^A
ATTRITIONING RUN FINES (mg/kg)														
HGADSL-1	108	52300	<0.077	6.4	917	16800	17300	13.3	498	1210	128	27.5	338	2970 R
HGADSL-2	96.5	64200	0.15	7.8	1230	22300	12700	16.3	386	1560	142	29.9	398	6600
HGADSL-3	93.3	72300	0.25	8.8	1390	25200	13600	16.0	404	1760	177	25.1	448	6400
HGADSL-4	106	67100	0.079	8.1	1300	23400	11700	18.5	366	1640	158	31.4	412	6400
HGADSL-5	128	63400	<0.079	7.5	1230	22100	11400	19.3	346	1560	172	28.4	389	2520 R
Average	106	63860	0.11	7.7	1213	21960	13340	16.7	400	1546	155	28.5	397	4978
Standard Dev.	13.6	7343	0.09	0.9	178	3136	2378	2.4	59	205	20	2.4	40	2046
%RSD	12.8	11.5	80.6	11.4	14.7	14.3	17.8	14.1	14.7	13.3	13.2	8.4	10.1	41.1
WASHING CYCLE FINES (mg/kg)														
HGWDSL-1	126	68900	0.26	8.4	1260	22700	21300	19.4	499	1620	191	24.7	409	4800
INITIAL RECYCLED WATER QUALITY (ug/L)														
HGMWA-001	<4.1	1510	<0.30	<2.6	5.2	102	1890	0.13	60.7	<9.2	7.4 U/J	<25.4	84.8	170
ATTRITIONING CYCLE RECYCLED WATER (ug/L)														
HGARWA-001	4.2	1530	<0.3	<2.6	20.5	410	857	0.28	35.1	33.7	5.6 U/J	<25.4	71.5 U	960
HGARWA-002	6.7	1730	<0.3	<2.6	32.1	622	303	0.43	16.9	45.4	6.9 U/J	<25.4	35.9 U	1500
HGARWA-003	13.3	4020	0.3	<2.6	75.6	1460	564	0.78	27.6	108	4.4 U/J	<25.4	51.4 U	2000
HGARWA-004	8.3	6940	0.5	<2.6	121	2550	674	0.59	37.6	189	6.6 U/J	<25.4	70.5 U	2500
HGARWA-005	7.5	7400	0.5	<2.6	130	2730	773	0.62	42.6	199	26.1 U/J	<25.4	75.6 U	2730
HGARWA-006	16.6	4800	0.3	<2.6	86.4	1650	930	1.40	33.8	126	18.1 U/J	<25.4	53.1 U	2600
HGARWA-007	13.9	4500	0.5	<2.6	76.9	1470	1180	0.96	40.1	110	13.3 U/J	<25.4	53.1 U	2700
Average	10.1	4417	0.3	<2.6	77.5	1556	754	0.72	33.4	116	11.6	<25.4	58.7	2141
Standard Dev.	4.5	2278	0.2	NA	40.9	873	280	0.37	8.7	63.5	8.1	NA	14.3	686
%RSD	45.0	51.6	46.4	NA	52.8	56.1	37.1	51.4	26.1	54.8	69.7	NA	24.3	32.0
WASHING CYCLE RECYCLED WATER (ug/L)														
HGWRWA-001	11.1	4550	0.30	<2.6	74	1460	1380	1.0	48	106	10.7 U/J	<25.4	65 U	2300

Table 3-34. Results of the Chemical and Radiochemical Analysis of Soils and Water Conducted for the Uranium Carbonate Run. (sheet 3 of 4)

Sample Identification	Uranium-235	Uranium-238	Cobalt-60	Cesium-137	Thorium-228	Potassium-40
ATTRITIONING CYCLE FEED SOIL (pCi/g)						
HGAFFSL-1	4.3 J	90 J	0.0851	0.127	2.05	10.9
HGAFFSL-2		187				
HGAFFSL-3		177				
HGAFFSL-4		127				
HGAFFSL-5	4.7 J	81 J	0.0754	0.126	1.77	10.0
Average	4.5	132	0.0803	0.127	1.91	10.5
Standard Dev.	0.3	48	0.0069	0.001	0.20	0.6
%RSD	6.3	36.6	8.5	0.6	10.4	6.1
ATTRITIONING CYCLE PROCESS OVERSIZE (pCi/g)						
HGAOSL-1	0.45 J	8.8 J	<0.03	0.0726	1.01	14.9
HGAOSL-2		3.2				
HGAOSL-3		6.7				
HGAOSL-4		6.3				
HGAOSL-5	0.15 J	2.7 J	<0.04	<0.04	0.656	12.7
Average	0.3	5.5	<0.04	0.046	0.8	13.8
Standard Dev.	0.2	2.7	---	0.037	0.3	1.6
%RSD	70.7	45.7	---	80.3	30.0	11.3
WASHING CYCLE CLEAN SAND (pCi/g)						
HGWCSL-1	1.3 J	27 J	<0.05	0.291	2.57	9.53
HGWCSL-2		33				
HGWCSL-3		28				
HGWCSL-4	1.4	26	<0.06	0.239	2.60	8.39
Average	1.4	28.4	<0.06	0.265	2.59	9.0
Standard Dev.	0.1	3.1	---	0.0	0.02	0.8
%RSD	5.2	11.0	---	13.9	0.8	9.0

Table 3-34. Results of the Chemical and Radiochemical Analysis of Soils and Water Conducted for the Uranium Carbonate Run. (sheet 4 of 4)

Sample Identification	Uranium-235	Uranium-238	Cobalt-60	Cesium-137	Thorium-228	Potassium-40
ATTRITIONING RUN FINES (pCi/g)						
HGADSL-1	62 R	990 R	0.784	0.545	14.5	10.2
HGADSL-2		2200				
HGADSL-3		2133				
HGADSL-4		2133				
HGADSL-5	54 R	840 R	1.07	0.819	23.9	10.1
Average	58	1659	0.93	0.682	19.2	10.2
Standard Dev.	6	682	0.20	0.194	6.6	0.1
%RSD	9.8	41.1	21.8	28.4	34.6	0.7
WASHING CYCLE FINES (pCi/g)						
HGWDSL-1		1600				
INITIAL RECYCLED WATER QUALITY (pCi/L)						
HGMWA-001		57				
ATTRITIONING CYCLE RECYCLED WATER (pCi/L)						
HGARWA-001	22	320	<4.3	<4.7	<7.9	<106
HGARWA-002		500				
HGARWA-003		667				
HGARWA-004		833				
HGARWA-005	43	910	<2.8	<3.7	10.9	<82
HGARWA-006		867				
HGARWA-007		900				
Average	33	714	<3.6	<4.2	<7.9	<94
Standard Dev.	15	229	---	---	---	---
%RSD	45.7	32.0	---	---	---	---
WASHING CYCLE RECYCLED WATER (pCi/L)						
HGWRWA-001	36	790	<3.8	<4.3	<7.6	<96

^ Results for Total Uranium and Uranium-238 are converted between micrograms and pCi using the following formula. Total Uranium (ug/L or mg/kg) = Uranium-238 (pCi/L or pCi/g) x3.0.

Table 3-35. Results of the Chemical and Radiochemical Analysis of Soil Fractions
Generated from the Uranium Carbonate Run Products. (sheet 1 of 2)

Sample Identification	Fraction	Silver	Aluminum	Beryllium	Cadmium	Concentration in milligrams/kilograms (mg/kg) unless noted								Lead	Antimony	Zinc	Total Uranium	Uranium as U-238 (pCi/g) ⁶
					Chromium	Copper	Iron	Mercury	Manganese	Nickel								
FEED SOIL																		
HGAF1SL-FRCA	(+37.5-50mm)	<0.58	4800	0.082	<0.30	28.4	41.1	13500	0.057	228	14.2	1.0	6.4	13.9	3.3	1.1		
HGAF1SL-FRCB	(25-37.5mm)	<0.57	3730	0.19	<0.29	29.6	70.8	22600	0.054	304	17.4	1.9	8.3	29.1	3.9	1.3		
HGAF1SL-FRCC	(12.5-25mm)	<0.057	4660	0.21	0.39	36.7	111	26700	0.092	315	24.3	2.3	7.3	31.3	12	4.0		
HGAF1SL-FRCD	(4.75-12.5mm)	7	5440	0.18	0.39	52.5	560	29000	0.67	327	56.1	6.0	6.9	40.7	76	25		
HGAF1SL-FRCE	(2.0-4.75mm)	38.4	11900	0.43	1.3	189	3460	24500	4.2	281	254.0	28.3	9.4	75.4	550	183		
HGAF1SL-FRCF	(0.425-2.0mm)	35.1	12300	0.52	1.7	178	3590	23700	2.3	297	292.0	24.5	7.8	91.6	480	160		
HGAF1SL-FRCG	(0.25-0.425mm)	27.6	11900	0.47	1.1	155	3330	18100	1.2	300	296.0	26.9	7.1	86.0	430	143		
HGAF1SL-FRCH	(0.15-0.25mm)	30.4	29100	0.99	3.3	543	9440	18500	7.4	322	673.0	52.7	16.1	180.0	2400	800		
HGAF1SL-FRCI	(0.075-0.15mm)	33.9	45600	1.3	5.5	929	15900	16300	13.1	356	1030.0	128.0	21.7	276.0	3700	1233		
HGAF1SL-FRCJ	(0.045-0.075mm)	46.6	43800	1.1	5.4	880	15400	13800	12.5	360	974.0	134.0	15.9	272.0	3200	1067		
HGAF1SL-FRCK	(<0.045)	90.4	70900	1.7	9.1	1350	26300	10100	21.6	335	1670	207	28.8	442	3900	1300		
HGAF2SL-FRCA	(+37.5-50mm)	<0.57	2170	0.22	0.76	41.1	67.7	27700	0.054	284	20	2.5	9.5	24.1	4.9	1.6		
HGAF2SL-FRCB	(25-37.5mm)	<0.57	3070	0.13	<0.29	28.6	64	19200	0.068	239	16.9	1.9	<3.3	23.5	4.6	1.5		
HGAF2SL-FRCC	(12.5-25mm)	<0.57	3080	0.16	0.42	30.1	89.4	20600	0.071	251	21.4	2	5.2	23.1	8.5	2.8		
HGAF2SL-FRCD	(4.75-12.5mm)	8.3	5940	0.31	<0.26	66.4	546	37500	0.42	422	61.1	5	<2.5	44.9	40	13		
HGAF2SL-FRCE	(2.0-4.75mm)	37.6	12200	0.48	1.3	170	3120	36800	3.6	354	224	20.1	10.5	80.6	540	180		
HGAF2SL-FRCF ⁶	(0.425-2.0mm)	<0.57	3270	0.22	<0.29	28.4	63.9	30100	<0.050	284	17.5	2.4	6.6	31.8	3.6	1.2		
HGAF2SL-FRCG	(0.25-0.425mm)	30	13100	0.56	1	183	3890	18400	3.2	249	315	28.5	8.1	95.3	580	193		
HGAF2SL-FRCH	(0.15-0.25mm)	20.9	27000	0.95	3.1	482	8730	19000	5.9	313	626	61.4	14.7	171	2200	733		
HGAF2SL-FRCI	(0.075-0.15mm)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		
HGAF2SL-FRCJ	(0.045-0.075mm)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		
HGAF2SL-FRCK	(<0.045)	48.9	68300	1.7	8.1	1240	25400	11400	20.9	356	1610	224	24.4	433	4900	1633		
PROCESS OVERSIZE																		
HGAO1SL-FRCA	(+37.5-50mm)	0.95	5150	0.65	<0.26	32	65.4	23400	<0.050	228	14.9	<0.81	8.9	23	1.9	0.6		
HGAO1SL-FRCB	(25-37.5mm)	1.1	3040	0.61	<0.25	35.9	67.5	26400	<0.050	322	19.9	<0.79	8.4	31	2.9	1.0		
HGAO1SL-FRCC	(12.5-25mm)	1.3	3220	0.63	<0.26	30.8	68.9	24400	<0.050	279	19.2	<0.77	8	29.4	4.4	1.5		
HGAO1SL-FRCD	(4.75-12.5mm)	3.4	3770	0.67	<0.25	39	223	27000	0.21	299	31.5	<0.77	8.7	37	25	8.3		
HGAO1SL-FRCE	(2.0-4.75mm)	2.6	4110	0.19	<0.29	32.5	368	23400	0.34	257	43	4.8	8.1	36.2	54	18		
HGAO1SL-FRCF	(0.425-2.0mm)	33.8	13800	0.59	1.5	184	3370	38500	3	381	246	28.3	12	94.3	860	287		
HGAO1SL-FRCG	(0.25-0.425mm)	40.6	64400	1.4	7.4	1080	23800	16200	22.5	312	1500	278	21.4	416	6900	2300		
HGAO2SL-FRCA	(+37.5-50mm)	0.93	5100	0.6	<0.26	33.5	54.8	22800	<0.050	251	16.7	<0.81	6	22.7	3.8	1.3		
HGAO2SL-FRCB	(25-37.5mm)	1.2	4250	0.62	<0.25	34.3	60.7	29000	<0.050	329	20	<0.79	9.9	31.9	3.9	1.3		
HGAO2SL-FRCC	(12.5-25mm)	1.1	3720	0.65	<0.26	29.8	62.8	22900	<0.050	272	18.5	<0.78	7.1	28.2	5.3	1.8		
HGAO2SL-FRCD	(4.75-12.5mm)	1.6	3560	0.67	<0.26	30	124	25800	0.086	286	23.8	1.2	8.7	32.8	11	3.7		
HGAO2SL-FRCE	(2.0-4.75mm)	12	5990	0.3	0.92	75.8	1110	32500	1.1	341	88.1	9.6	11.1	53.2	230	77		
HGAO2SL-FRCF	(0.425-2.0mm)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		
HGAO2SL-FRCG	(0.25-0.425mm)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		

Table 3-35. Results of the Chemical and Radiochemical Analysis of Soil Fractions
Generated from the Uranium Carbonate Run Products. (sheet 2 of 2)

Sample Identification	Fraction	Silver	Aluminum	Beryllium	Cadmium	Concentration in milligrams/kilograms (mg/kg) unless noted								Lead	Antimony	Zinc	Total Uranium	Uranium as U-238 (pCi/g) ^B
CLEAN SAND																		
HGWC1SL-FRCF	(0.425-2.0mm)	3.8	5030	0.26	0.52	35.3	926	26100	0.24	285	91.9	7.4	8.3	55	48	16		
HGWC1SL-FRC	(0.25-0.425mm)	5	6600	0.3	1.2	45.6	1410	23200	0.32	294	145	13.3	5.7	61.8	83	28		
HGWC1SL-FRC	(0.15-0.25mm)	6.3	7210	0.3	0.86	51.2	1720	19700	4.1	285	170	18.9	4.9	64.4	110	37		
HGWC1SL-FRCI	(0.075-0.15mm)	7.4	7300	0.29	0.9	54.7	1870	17200	0.4	265	167	28.7	4.9	66.7	210	70		
HGWC1SL-FRCJ	(0.045-0.075mm)	37.3	41500	1.4	4.1	704	13200	29400	7.9	487	856	334	19.4	344	4300	1433		
HGWC1SL-FRCK	(<0.045)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		
HGWC2SL-FRCF	(0.425-2.0mm)	3	4870	0.28	<0.30	31.6	786	28500	0.14	287	79.9	9.6	7.3	55	61	20		
HGWC2SL-FRC	(0.25-0.425mm)	4.7	5950	0.27	0.9	40.7	1330	21400	0.24	269	135	11.8	8.4	57.7	79	26		
HGWC2SL-FRC	(0.15-0.25mm)	7.5	6940	0.3	0.76	52.5	1730	1880	0.21	263	164	12.5	3.9	62.2	170	57		
HGWC2SL-FRCI	(0.075-0.15mm)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		
HGWC2SL-FRCJ	(0.045-0.075mm)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		
HGWC2SL-FRCK	(<0.045)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		

^a Results of the analysis of this sample are inconsistent with the associated data. It appears that an aliquot of a more coarse fraction was prepared and incorrectly labeled as HGAF2SL-FRCF. Data for this sample is not included in the data evaluation section. Instead, the average concentration of the adjacent fractions has been used in the data evaluation.

^b Results for Total Uranium in milligrams/kilogram have been converted to Uranium as Uranium-238 in pCi/g using the following formula: Total Uranium (mg/kg) = Uranium-238 (pCi/g) x 3.0

Table 3-36. Copper Distribution in Process Products from the Uranium Carbonate Run.

Fraction (mm)	Distribution (%)	FEED			Distribution (%)	OVERSIZE			Distribution (%)	SAND			
		Cu-conc. (mg/kg)	Cu-load (mg/kg)	Cu-load (%)		Cu-conc. (mg/kg)	Cu-load (mg/kg)	Cu-load (%)		Cu-conc. (mg/kg)	Cu-load (mg/kg)	Cu-load (%)	
INITIAL SAMPLING EVENT													
(+37.5-50)	8.1	41.1	3.3	0.1	10.7	65.4	7.0	1.9	---	---	---	---	---
(25-37.5)	11.3	70.8	8.0	0.2	21.6	67.5	14.6	3.9	---	---	---	---	---
(12.5-25)	16.4	111	18.2	0.5	30.9	68.9	21.3	5.7	---	---	---	---	---
(4.75-12.5)	14.6	560	81.8	2.1	22.6	223	50.4	13.4	---	---	---	---	---
(2.0-4.75)	9.3	3460	321.8	8.4	10.6	368	39.0	10.4	0.1	926 ^A	0.9	0.1	0.1
(0.425-2.0)	22.8	3590	818.5	21.3	3.0	3370	101.1	26.9	71.8	926	664.9	53.4	53.4
(0.25-0.425)	6.7	3330	223.1	5.8	0.6	23800	142.8	38.0	18.4	1410	259.4	20.8	20.8
(0.15-0.25)	1.7	9440	160.5	4.2	---	---	---	---	6.2	1720	106.6	8.6	8.6
(0.075-0.15)	1.1	15900	174.9	4.6	---	---	---	---	2.2	1870	41.1	3.3	3.3
(0.045-0.075)	0.7	15400	107.8	2.8	---	---	---	---	0.4	13200	52.8	4.2	4.2
(<0.045)	7.3	26300	1919.9	50.0	---	---	---	---	0.9	13200 ^A	118.8	9.5	9.5
Calculated Totals	100		3838	100	100		376	100	100		1245	100	100
Measured Bulk Concentration			1680				217				1140		
FINAL SAMPLING EVENT													
(+37.5-50)	11.0	67.7	7.4	0.3	32.7	54.8	17.9	9.5		---	---	---	---
(25-37.5)	19.0	64	12.2	0.5	26.4	60.7	16.0	8.5		---	---	---	---
(12.5-25)	22.1	89.4	19.8	0.8	23.5	62.8	14.8	7.8		---	---	---	---
(4.75-12.5)	10.9	546	59.5	2.3	11.4	124	14.1	7.5		---	---	---	---
(2.0-4.75)	6.3	3120	196.6	7.5	5.2	1110	57.7	30.6	0	0	0.0	0.0	0.0
(0.425-2.0)	18.7	3505 ^C	655.4	25.0	0.6	3370 ^B	20.2	10.7	78.1	786	613.9	60.4	60.4
(0.25-0.425)	4.9	3890	190.6	7.3	0.2	23800 ^B	47.6	25.3	17.3	1330	230.1	22.6	22.6
(0.15-0.25)	1.1	8730	96.0	3.7	---	---	---	---	3.1	1730	53.6	5.3	5.3
(0.075-0.15)	0.8	15900 ^B	127.2	4.8	---	---	---	---	0.7	1870 ^B	13.1	1.3	1.3
(0.045-0.075)	0.6	15400 ^B	92.4	3.5	---	---	---	---	0.2	13200 ^B	26.4	2.6	2.6
(<0.045)	4.6	25400	1168.4	44.5	---	---	---	---	0.6	13200 ^A	79.2	7.8	7.8
Calculated Totals	100		2626	100	100		188	100	100		1016	100	100
Measured Bulk Concentration			1570				99				1130		

^A The sample of this particle size fraction was not analyzed due to insufficient sample mass. The material generated from this fraction was combined with the material from the next larger or smaller particle size fraction, as appropriate, generated from the same sampling event. The results of the analysis of the combined sample shown for calculation purposes.

^B The sample of this particle size fraction was not analyzed due to insufficient sample mass. The material generated from this fraction was combined with the material from the same particle size fraction generated during by particle size analysis of the first sample collected from the run. The concentration of the composite sample is shown for calculation purposes.

^C Results of the analysis of this sample are inconsistent with the associated data. It appears that an aliquot of a more coarse fraction was prepared and incorrectly labeled as HGAF2SL-FRCF. Data for this sample is not included in the data evaluation section. Instead, the average concentration of the adjacent fractions has been used in the data evaluation.

Table 3-37. Uranium-238 Distribution in Process Products from the Uranium Carbonate Run.

Fraction (mm)	Distribution (%)	FEED			Distribution (%)	OVERSIZE			Distribution (%)	SAND		
		U238-conc (pCi/g)	U238-load (pCi/g)	U238-load (%)		U238-conc (pCi/g)	U238-load (pCi/g)	U238-load (%)		U238-conc. (pCi/g)	U238-load (pCi/g)	U238-load (%)
INITIAL SAMPLING EVENT												
(+37.5-50)	8.1	1.1	0.1	0.0	10.7	0.6	0.1	0.3	---			
(25-37.5)	11.3	1.3	0.1	0.1	21.6	1.0	0.2	0.8	---			
(12.5-25)	16.4	4.0	0.7	0.3	30.9	1.5	0.5	1.7	---			
(4.75-12.5)	14.6	25.3	3.7	1.9	22.6	8	1.9	7.0	---			
(2.0-4.75)	9.3	183	17.1	8.6	10.6	18	1.9	7.1	0.1	16	0.0	0.0
(0.425-2.0)	22.8	160	36.5	18.5	3.0	287	8.6	31.9	71.8	16	11.5	29.4
(0.25-0.425)	6.7	143	9.6	4.9	0.6	2300	13.8	51.3	18.4	28	5.1	13.0
(0.15-0.25)	1.7	800	13.6	6.9	---				6.2	37	2.3	5.8
(0.075-0.15)	1.1	1233	13.6	6.9	---				2.2	70	1.5	3.9
(0.045-0.075)	0.7	1067	7.5	3.8	---				0.4	1433	5.7	14.7
(<0.045)	7.3	1300	94.9	48.1	---				0.9	1433 ^A	12.9	33.0
Calculated Totals	100		197	100	100		27	100	100		39	100
Measured Bulk Concentration			90				8.8				27	
FINAL SAMPLING EVENT												
(+37.5-50)	11.0	1.6	0.2	0.1	32.7	1.3	0.4	3.5	---	---		
(25-37.5)	19.0	1.5	0.3	0.2	26.4	1.3	0.3	2.9	---	---		
(12.5-25)	22.1	2.8	0.6	0.4	23.5	1.8	0.4	3.5	---	---		
(4.75-12.5)	10.9	13.3	1.5	0.9	11.4	3.7	0.4	3.5	---	---		
(2.0-4.75)	6.3	180	11.3	7.2	5.2	77	4.0	33.5	0	20	0.0	0.0
(0.425-2.0)	18.7	187 ^C	34.9	22.1	0.6	287 ^B	1.7	14.5	78.1	20	15.9	46.5
(0.25-0.425)	4.9	193	9.5	6.0	0.2	2300 ^B	4.6	38.7	17.3	26	4.6	13.3
(0.15-0.25)	1.1	733	8.1	5.1	---	---			3.1	57	1.8	5.1
(0.075-0.15)	0.8	1233 ^B	9.9	6.3	---	---			0.7	70 ^B	0.5	1.4
(0.045-0.075)	0.6	1067 ^B	6.4	4.1	---	---			0.2	1433 ^B	2.9	8.4
(<0.045)	4.6	1633	75.1	47.6	---	---			0.6	1433 ^A	8.6	25.2
Calculated Totals	100		158	100	100		12	100	100		34	100
Measured Bulk Concentration			81				2.7				26	

^A The sample of this particle size fraction was not analyzed due to insufficient sample mass. The material generated from this fraction was combined with the material from the next larger or smaller particle size fraction, as appropriate, generated from the same sampling event. The results of the analysis of the combined sample shown for calculation purposes.

^B The sample of this particle size fraction was not analyzed due to insufficient sample mass. The material generated from this fraction was combined with the material from the same particle size fraction generated during by particle size analysis of the first sample collected from the run. The concentration of the composite sample is shown for calculation purposes.

^C Results of the analysis of this sample are inconsistent with the associated data. It appears that an aliquot of a more coarse fraction was prepared and incorrectly labeled as HGAF2SL-FRCF. Data for this sample are not included in the data evaluation section. Instead, the average concentration of the adjacent fractions has been used in the data evaluation.

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Table 3-38. Estimated Contaminant Load Before and After Attritioning.

Particle Size Fraction (mm)	% Distribution in the Feed	Sand Fraction Before Attritioning Cu-Conc. (mg/kg)	Sand Fraction Before Attritioning Cu-Load (mg/kg)	Sand Fraction After Attritioning Cu-Conc. (mg/kg)	Sand Fraction After Attritioning Cu-Load (mg/kg)	Sand Fraction Before Attritioning U238-Conc. (pCi/g)	Sand Fraction Before Attritioning U238-Load (pCi/g)	Sand Fraction After Attritioning U238-Conc. (pCi/g)	Sand Fraction After Attritioning U238-Load (pCi/g)
INITIAL SAMPLING EVENT									
0.425-2.0	22.8	3590	818.5	926	217.8	160	36.5	16	3.6
0.25-0.425	6.7	3330	223.1	1410	94.5	143	9.6	28	1.9
0.15-0.25	1.7	9440	160.5	1720	29.2	800	13.6	37	0.6
0.075-0.15	1.1	15900	174.9	1870	20.6	1233	13.6	70	0.8
Total	32.3		1377		362.1		73		6.9
Feed Load Copper - 3838 mg/kg					Feed Load Uranium - 197 pCi/g				
FINAL SAMPLING EVENT									
0.425-2.0	18.7	3505	655.4	786	147	187	34.9	20.3	3.8
0.25-0.425	1.1	8730	96	1330	19	193	9.5	26.3	1.3
0.15-0.25	1.7	9440	160.5	1730	29.2	733	8.1	56.7	0.6
0.075-0.15	0.8	15900	127.2	1870	15	1233	9.9	70	0.6
Total	22.3		1039.1		210.2		62.3		6.3
Feed Load Copper - 2626 mg/kg					Feed Load Uranium 158 pCi/g				

Table 3-39. Comparison of Calculated Soil Fraction Distribution Based on Feed Particle-Size Distribution and Fraction Distribution of Field Test, Uranium Carbonate Run.

Fractions	FRACTION DISTRIBUTION (%), DRY WEIGHT BASIS			
	Original Soil		Pre-Screened Soil (fraction < 50 mm)	
	Calculated	Field Test	Calculated	Field Test
Gross Oversize (> 50 mm)	17.6	17.6	---	---
Oversize (2.0 - 50 mm)	53.2	59.6	64.5	72.3
Sand (2.0 - 0.075 mm)	23.8	18.6	28.9	22.6
Fines (< 0.075 mm)	5.5	4.2	6.6	5.0
Total	100	100	100	100

Shading represents that these numbers are based on fraction of gross oversize (> 50 mm) as determined from Pre-Screening.

Table 3-40. Total Mass Balance and Volume Reduction by Weight for Uranium Carbonate Run (Including Material > 50 mm).

	Mass (tons)	
Total Mass Processed		
Fraction (> 50 mm) ^A	9.2	
Plant Feed (< 50 mm)	43.1	
TOTAL	52.3	(A)
Total Mass Clean		
Oversize (2.0 - 50 mm)	29.6	
Sand (0.075 - 2.0 mm)	10.0	
TOTAL	39.6	(C)
Total Mass Contaminated		
Sludge Cake (< 0.075 mm)	4.5	(D)
Secondary Waste ^B	0.0	(Esw)
TOTAL	4.5	

PERCENT VOLUME REDUCTION BY WEIGHT (%): $(A-D-Esw)*100/A = 91.4 \%$

^A Calculated based on pre-screening data

^B No secondary waste was generated as a result of the boiling off of process water.

For complete evaluation of the amount of volume reduction by weight, the total mass of secondary waste consisting of dissolved and suspended solids in the process water after processing was determined to be neglectable for each Run (Section 3.4.3.4).

Table 3-41. Results of Fraction Analysis (by XRF), Oversize Attritioning Test.

Fraction (mm)	Uranium Carbonate Run - Sampling Event			After Attrition Test	Removal Efficiency Through Attritioning (%)
	Initial	Final	Average		
COPPER (mg/kg)					
37.5 - 50	< 75	< 75	< 75	88	ND
25 - 37.5	< 75	< 75	< 75	< 75	ND
12.5 - 25	76	79	78	< 75	> 4.0 %
4.75-12.5	360	158	259	180	31%
2.0-4.75	565	1116	841	471	44%
URANIUM (pCi/g)					
37.5 - 50	<8	<8	<8	<8	ND
25 - 37.5	<8	<8	<8	<8	ND
12.5 - 25	<8	<8	<8	<8	ND
4.75-12.5	12	<8	<8	17	ND
2.0-4.75	19	52	36	19	46%

ND: No positive removal efficiency determined for specific fraction.

Table 3-42. Results of TCLP Analyses of Samples of Sludge Cake
Generated During the Soil Washing Study.

Constituent	TCLP Regulatory Limit	Pretest Run HPDSL-TC	Verification Run HVDSL-TC	Replication Run HRDSL-TC	Uranium Carbonate Run HGWDSL-TC
Metals (ug/L)					
Arsenic	5,000	<26.5	32	48.4	<26.5
Barium	100,000	1970	967	903	2160
Cadmium	1,000	3.9	4.3	4.2	13.5
Chromium	5,000	41.9	35.1	27.1	13.5
Lead	5,000	<27.8	<27.8	<27.8	<27.8
Mercury	200	<0.1	<0.1	<0.1	0.11
Selenium	1,000	<51.1	<51.1	<51.1	<51.1
Silver	5,000	<5.7	<5.7	<5.7	<5.7
Pesticides/Herbicides (ug/L)					
2,4-D	10,000	<10	<10	<10	<10
2,4,5-TP (silvex)	1,000	<5	<5	<5	<5
2,4,5-T	NA	<5	<5	<5	<5
Heptachlor	8	<0.11	<0.11	<0.11	<0.11
alpha-Chlordane	30	<0.11	<0.11	<0.11	<0.11
gamma-Chlordane	30	<0.11	<0.11	<0.11	<0.11
gamma-BHC (lindane)	400	<0.11	<0.11	<0.11	<0.11
Endrin	20	<0.21	<0.21	<0.22	<0.23
Methoxychlor	10,000	<1.1	<1.1	<1.1	<1.1
Toxaphene	500	<2.1	<2.1	<2.2	<2.3
Heptachlor Epoxide	8	<0.11	<0.11	<0.11	<0.11
Volatile Organic Compounds (ug/L)					
Vinyl Chloride	200	<100	<100	<100	<100
1,1-Dichloroethene	700	<50	<50	<50	<50
Chloroform	6,000	<50	<50	<50	<50
1,2-Dichloroethane	500	<50	<50	<50	<50
2-Butanone (Methylethylketone)	200,000	<100	<100	<100	<100
Carbon Tetrachloride	500	<50	<50	<50	<50
Trichloroethene	500	<50	<50	<50	<50
Benzene	500	<50	<50	<50	<50
Tetrachloroethene	700	<50	<50	<50	<50
Chlorobenzene	100,000	<50	<50	<50	<50
Semivolatile Organic Compounds (ug/L)					
Pyridine	5,000	<100	<100	<100	<100
1,4-Dichlorobenzene	7,500	<100	<100	<100	<100
2-Methylphenol (o-Cresol)	200,000	<100	<100	<100	<100
3- and 4-Methylphenol (m- and p-Cresol)	200,000	<100	<100	<100	<100
Hexachloroethane	3,000	<100	<100	<100	<100
Nitrobenzene	2,000	<100	<100	<100	<100
Hexachlorobutadiene	500	<100	<100	<100	<100
2,4,6-Trichlorophenol	2,000	<100	<100	<100	<100
2,4,5-Trichlorophenol	400,000	<500	<500	<500	<500
2,4-Dinitrotoluene	130	<100	<100	<100	<100
Hexachlorobenzene	130	<100	<100	<100	<100
Pentachlorophenol	100,000	<500	<500	<500	<500

Table 3-43. Summary of Preparation and Process Runs.

Event Description	Date	Material	Processing Time	Plant Feed Processed Tons	Average Tons/Hour	Rough Feed to Screen All Tons	Gross Undersize Mass Weighed Tons	Gross Oversize Mass Weighed Tons
Pre-Screen 1	23-Mar-94	From Stockpiles A, B and C	N/A		N/A	25.5	16.2	2.1
Pre-Screen 2	24-Mar-94	From Stockpiles A, B and C	N/A		N/A	88.5	71.9	7.3
Pre-Screen 3	25-Mar-94	From Stockpiles A, B and C	N/A		N/A	130.9	94.4	21.1
Pre-Screen 4	28-Mar-94	From Stockpiles A, B and C	N/A		N/A	28.4	16.2	2.1
Pre-Test Run 1	29-Mar-94 AM	50 mm Undersize From Pre-Screening	1:53	16.4	8.7			
Pre-Test Run 2	29-Mar-94 PM	50 mm Undersize From Pre-Screening	1:06	16.9	15.4			
Verification Run	6-Apr-94	50 mm Undersize From Pre-Screening	4:44	79.8	16.9			
Replication Run	11-Apr-94	50 mm Undersize From Pre-Screening	5:45	52.1	9.1			
Uranium Carbonate Pre-Screening	12-Apr-94	From Uranium Carbonate Gross Stockpile	N/A		N/A	75.0	60.1	12.8
Uranium Carbonate Run	13-Apr-94	50 mm Undersize From Uranium Carbonate Pre-Screening	2:42	43.1	16.0			

Table 3-44. Summary of Process Feeds and Product Weighing Results.

	PRE-TEST, VERIFICATION AND REPLICATION RUN								URANIUM CARBONATE RUN		
	Contract Target (Tons)	Pre-Screening (Tons)	Pre-Test 1 (Tons)	Pre-Test 2 (Tons)	Pre-Test Total (Tons)	Verification Run (Tons)	Replication Run (Tons)	Grand Total Wet (Tons)	Contract Target (Tons)	Pre-Screening (Tons)	Uranium Carbonate Run (Tons)
TOTAL FEED	300.0	273.2						273.2	80.0	75.0 **	
GROSS OVERSIZE plus 50 mm		32.6								12.8	
GROSS UNDERSIZE minus 50 mm		198.7								60.1	
TEST PROCEDURE TARGET minus 50 mm					35.0	70.0	70.0	175.0			40.0
FED TO PLANT minus 50 mm			16.4	16.9	33.3	79.8	52.1 °	165.2			43.1
PROCESS OVERSIZE minus 50 mm plus 2 mm			10.5	9.4	19.9	62.9	40.2	123.0			29.6
SAND			3.1	2.3	5.4	16.0	10.9	32.4			10.0
SLUDGE CAKE					2.9	6.3	4.9	14.1			4.5
VOLUME REDUCTION					N/A	94.3%	93.2%	N/A			91.4%

Table 3-45. Soil Particle Size Distribution (Soils not Containing "Green Material").

Fraction (mm)	PRE-TEST RUN		VERIFICATION RUN		REPLICATION RUN		AVERAGE
	Pre-Process Composite	Pre-Test 1&2 Composite	Sampling Event Initial	Sampling Event Final	Sampling Event Initial	Sampling Event Final	
(> 50)	27.3	27.3	27.3	27.3	27.3	27.3	27.3
(37.5-50)	9.3	12.0	4.8	7.1	5.9	0.0	6.5
(25-37.5)	8.7	12.6	10.3	7.4	8.1	2.3	8.2
(12.5-25)	13.1	12.3	16.5	14.4	18.2	10.8	14.2
(4.75-12.5)	14.7	12.3	14.4	13.7	14.1	11.3	13.4
(2.0-4.75)	7.3	7.8	8.5	8.5	7.5	12.4	8.7
(0.425-2.0)	13.3	9.9	11.3	13.8	12.1	24.2	14.1
(0.25-0.425)	1.5	1.4	1.8	1.8	1.7	3.0	1.9
(0.15-0.25)	0.7	0.7	0.8	0.7	0.7	1.2	0.8
(0.075-0.15)	0.5	0.6	0.6	0.7	0.6	0.9	0.7
(0.045-0.075)	0.4	0.4	0.4	0.4	0.4	0.5	0.4
(<0.045)	3.3	2.9	3.3	4.1	3.4	6.0	3.8
Total	100	100	100	100	100	100	100

Table 3-46. Soil Feed Particle Size Distribution of Original Soil, Uranium Carbonate Run.

Fraction (mm)	DISTRIBUTION (%)		
	Sampling Event		Average
	Initial	Final	
(> 50)	17.6	17.6	17.6
(37.5-50)	6.7	9.1	7.9
(25-37.5)	9.3	15.7	12.5
(12.5-25)	13.5	18.2	15.9
(4.75-12.5)	12.0	9.0	10.5
(2.0-4.75)	7.7	5.2	6.5
(0.850-2.0)	8.5	5.6	7.1
(0.425-0.850)	10.3	9.8	10.1
(0.25-0.425)	5.5	4.0	4.8
(0.15-0.25)	1.4	0.9	1.2
(0.075-0.15)	0.9	0.7	0.8
(0.045-0.075)	0.6	0.5	0.6
(<0.045)	6.0	3.8	4.9
Total	100	100	100

Table 3-47. Summary of Average Concentrations of Constituents by Run. (sheet 1 of 4)

Sample Identification	Silver	Aluminum	Beryllium	Cadmium	Chromium	Copper	Iron	Mercury	Manganese	Nickel	Lead	Antimony	Zinc	Total Uranium
VERIFICATION RUN														
FEED SOIL (mg/kg)														
Average	2.3	5702	0.82	<0.26	50.2	145	40189	0.05	466	28.7	3.5	11.4	51.5	4.3
Standard Dev.	0.5	1098	0.14	NA	11	36	8116	0.03	84	5.3	0.8	2.5	8.1	1.4
%RSD	20.2	19.2	16.6	NA	21.8	24.9	20.2	69.7	18	18.3	23.2	21.4	15.7	31.1
PROCESS OVERSIZE (mg/kg)														
Average	0.5	2983	0.57	<0.25	17.7	37	22522	<0.051	250	11.6	1.5	6.9	31.5	1.1
Standard Dev.	0.2	427	0.11	NA	9.9	11	5393	NA	60	4.3	0.3	1.7	4.4	1
%RSD	46.2	14.3	18.5	NA	55.7	29.1	23.9	NA	24	37.1	22.9	25.5	14.1	92.4
CLEAN SAND (mg/kg)														
Average	1.6	3846	0.71	<0.27	9.7	117	23644	<0.053	289	14.3	3.9	9.7	48.4	4.4
Standard Dev.	0.2	261	0.07	NA	1.5	17	1396	NA	21	1.9	0.6	1.6	9.5	0.8
%RSD	15.1	6.8	10.4	NA	15	14.1	5.9	NA	7.3	13.3	16.3	16.6	19.7	15.1
FINES (mg/kg)														
Average	18.2	22156	0.49	1	58.7	972	34511	1.4	945	96.6	36.5	<7.0	110.1	54.8
Standard Dev.	1.6	7969	0.16	0.3	5.8	90	3483	0.3	82	9.6	8.8	NA	13	13.6
%RSD	8.9	36	31.7	31.5	9.9	9.3	10.1	23.7	8.7	10	24	NA	11.8	24.8
RECYCLED PROCESS WATER (ug/L)														
Average	<4.1	1301	0.8	<2.6	3.7	126	1362	<0.10	62.1	<9.2	12	<25.4	48.2	93.7
Standard Dev.	NA	976	0.1	NA	3.3	58	987	NA	48.1	NA	24	NA	26.2	46.8
%RSD	NA	75	16.3	NA	88.8	46.1	72.5	NA	77.5	NA	200	NA	54.3	50
REPLICATION RUN														
FEED SOIL (mg/kg)														
Average	1.3	3749	0.31	0.71	12.4	79.3	18540	0.07	242	12.8	3	3.2	30.6	3.6
Standard Dev.	0.4	585	0.05	0.15	3.3	35.2	2311	0.03	40	3.6	0.6	1.5	4.9	1.1
%RSD	31.5	15.6	15.8	21.1	26.8	44.4	12.5	49.6	16.5	28	20.4	45.8	16.1	31.9
PROCESS OVERSIZE (mg/kg)														
Average	0.63	2442	0.38	<0.26	10.1	24.8	14880	<0.051	173	7.4	1.3	6.4	26	1.4
Standard Dev.	0.09	650	0.08	NA	3.1	5.4	3045	NA	36	2.4	0.5	1.5	6.8	1
%RSD	14.7	26.6	20.4	NA	30.6	21.6	20.5	NA	21	32.5	38	23.1	26.2	73.9

Table 3-47. Summary of Average Concentrations of Constituents by Run. (sheet 2 of 4)

Sample Identification	Silver	Aluminum	Beryllium	Cadmium	Chromium	Copper	Iron	Mercury	Manganese	Nickel	Lead	Antimony	Zinc	Total Uranium
CLEAN SAND (mg/kg)														
Average	1.46	3852	0.72	<0.26	12.4	97.3	25750	<0.051	308	13.4	3.6	10.2	51.4	4.2
Standard Dev.	0.2	535	0.07	NA	4.4	14.8	2436	NA	27	2.1	1.4	2	4.9	1.2
%RSD	13.8	13.9	10.3	NA	35	15.3	9.5	NA	8.9	15.7	37.9	19.6	9.5	29.1
FINES (mg/kg)														
Average	13.2	24090	1.4	<0.72	50.2	714	36030	1.08	951	76.4	24.1	8.5	87.9	44.4
Standard Dev.	2.3	3277	0.2	NA	13.1	17.2	12.7	34.1	12.4	15.1	44.2	30.3	25.2	8
%RSD	17.8	13.6	15.9	NA	13.1	17.2	12.7	34.1	12.4	15.1	44.2	30.3	25.2	18.1
RECYCLED WATER (ug/L)														
Average	<4.1	1694	0.31	<2.6	5.2	86	1661	<0.10	43	12.6	5.7	<25.4	79.5	122
Standard Dev.	NA	1762	0.15	NA	3.4	35	1746	NA	43	5.6	8.4	NA	60.8	74
%RSD	NA	104.1	48.6	NA	65.5	40.2	105.1	NA	98.2	44.4	147.8	NA	76.5	60.7
URANIUM CARBONATE RUN														
ATTRITIONING CYCLE FEED SOIL (mg/kg)														
Average	23.8	10834	0.33	1.16	177	2768	31900	2.2	357	223	19.9	9.5	83.4	397
Standard Dev.	7.3	2803.4	0.11	0.46	50	1102	4199	0.5	31	77	6.3	1.2	29.5	145
%RSD	30.5	25.9	32.1	39.3	28.3	39.8	13.2	24.9	8.7	34.5	31.5	12.9	35.3	36.6
ATTRITIONING CYCLE PROCESS OVERSIZE (mg/kg)														
Average	2.3	3612	0.18	<0.29	34.6	199	23020	0.17	264	28.7	3	6.7	30.8	16.5
Standard Dev.	1.9	147	0.05	NA	3.9	102	2939	0.08	40	6.3	0.5	0.9	3.8	7.6
%RSD	79.5	4.1	29.1	NA	11.3	51	12.8	50.6	15.3	21.9	16	13.9	12.3	45.7
WASHING CYCLE CLEAN SAND (mg/kg)														
Average	6.6	5600	0.25	0.43	44.2	1180	22600	0.3	264	116	10.5	6.5	55	85.3
Standard Dev.	1.1	332	0.02	0.11	5.3	152	4868	0	44	10	1.8	2	4.2	9.4
%RSD	16.2	5.9	8.5	25.2	12	12.9	21.5	1.7	16.5	9	17.2	30.6	7.7	11
ATTRITIONING RUN FINES (mg/kg)														
Average	106	63860	0.11	7.7	1213	21960	13340	16.7	400	1549	155	28.5	397	4978
Standard Dev.	13.6	7343	0.09	0.9	178	3136	2378	2.4	59	205	20	2.4	40	2046
%RSD	12.8	11.5	80.6	11.4	14.7	14.3	17.8	14.1	14.7	13.3	13.2	8.4	10.1	41.1
ATTRITIONING CYCLE RECYCLED WATER (ug/L)														
Average	10.1	4417	0.3	<2.6	77.5	1556	754	0.72	33.4	116	11.6	<25.4	58.7	2141
Standard Dev.	4.5	2278	0.2	NA	40.9	873	280	0.37	8.7	63.5	8.1	NA	14.3	686
%RSD	45	51.6	46.4	NA	52.8	56.1	37.1	51.4	26.1	54.8	69.7	NA	24.3	32

Table 3-47. Summary of Average Concentrations of Constituents by Run. (sheet 3 of 4)

Sample Identification	Uranium-235	Uranium-238	Cobalt-60	Cesium-137	Thorium-228	Potassium-40
VERIFICATION RUN						
FEED SOIL (pCi/g)						
Average	0.033	1.4	0.047	0.042	0.47	12.9
Standard Dev.	0.008	0.47	0.003	0.0066	0.015	2.3
%RSD	23.9	33.4	5.8	15.8	3.1	17.5
PROCESS OVERSIZE (pCi/g)						
Average	<0.006	0.5	<0.02	<0.02	0.43	9.7
Standard Dev.	---	0.3	---	---	0.018	1.6
%RSD	---	69.4	---	---	4.1	16.3
CLEAN SAND (pCi/g)						
Average	0.051	2.1	0.058	0.057	0.47	9.4
Standard Dev.	0.003	1.9	0.0091	0.018	0.000	0.1
%RSD	5.5	90.6	15.8	30.8	0.000	1.5
FINES (pCi/g)						
Average	0.6	18.2	0.7	0.3	1.1	17.6
Standard Dev.	0.2	4.5	0.000	0.000	0.0	0.8
%RSD	35.1	24.8	2.2	10.2	4.5	4.8
RECYCLED PROCESS WATER (pCi/L)						
Average	<0.3	0.031	<3.6	<3.9	<6.7	85
Standard Dev.	---	0.016	---	---	---	---
%RSD	---	50.2	---	---	---	---
REPLICATION RUN						
FEED SOIL (pCi/g)						
Average	0.041	0.97	0.05	0.05	0.49	10.5
Standard Dev.	0.016	0.33	---	---	0.013	0.9
%RSD	40.2	33.5	---	---	2.8	8.8
PROCESS OVERSIZE (pCi/g)						
Average	<0.008	0.5	<0.02	<0.02	0.47	10.4
Standard Dev.	---	0.3	---	---	0.013	0.3
%RSD	---	73.9	---	---	2.7	2.7

Table 3-47. Summary of Average Concentrations of Constituents by Run. (sheet 4 of 4)

Sample Identification	Uranium-235	Uranium-238	Cobalt-60	Cesium-137	Thorium-228	Potassium-40
CLEAN SAND (pCi/g)						
Average	0.054	1.4	<0.04	0.045	0.5	9.3
Standard Dev.	0.004	0.4	---	0.0013	0.01	0.6
%RSD	6.6	28.2	---	2.8	1.4	6.7
FINES (pCi/g)						
Average	0.49	14.9	0.70	0.27	1.3	19.2
Standard Dev.	0.11	2.7	0.31	0.12	0.25	1.4
%RSD	21.9	18.4	44.1	44.8	19.3	7.4
RECYCLED WATER (pCi/L)						
Average	2.8	41	<3.4	<4.0	<6.8	<83
Standard Dev	2.5	25	---	---	---	---
%RSD	90	61	---	---	---	---
URANIUM CARBONATE RUN						
ATTRITIONING CYCLE FEED SOIL (pCi/g)						
Average	4.5	132	0.080	0.13	1.9	5.5
Standard Dev	0.3	49	0.0069	0.001	0.2	6.3
%RSD	6.3	37	8.5	0.6	10	114
ATTRITIONING CYCLE PROCESS OVERSIZE (pCi/g)						
Average	0.3	5.5	<0.04	0.046	0.8	13.8
Standard Dev	0.2	2.6	---	0.037	0.3	1.6
%RSD	70.7	46.1	---	80.3	30	11.3
WASHING CYCLE CLEAN SAND (pCi/g)						
Average	1.4	28.5	<0.06	0.3	2.6	9
Standard Dev	0.1	3.1	---	0	0.02	0.8
%RSD	5.2	10.9	---	13.9	0.8	9
ATTRITIONING RUN FINES (pCi/g)						
Average	58	1659	0.93	0.68	19.2	10.2
Standard Dev	6	682	0.2	0.19	6.6	0.1
%RSD	9.8	41.1	21.8	28.4	34.6	0.7
ATTRITIONING CYCLE RECYCLED WATER (pCi/L)						
Average	33	714	<3.6	<4.2	<7.9	<94
Standard Dev.	15	229	---	---	---	---
%RSD	45.7	32	---	---	---	---

4.0 QUALITY ASSURANCE/QUALITY CONTROL

Sample collection, management, analysis, and sample documentation were completed in accordance with the procedures described in the *Quality Assurance Project Plan for the Soil Washing Physical Separations Test, 300-FF-1 Operable Unit* (QAPjP) (ART 1994a).

4.1 DATA QUALITY OBJECTIVES

The data quality objectives (DQOs) for this project were specified in the QAPjP (ART 1994a). Quantitative DQOs are presented Table 4-1 and include the applicable EPA Level of Data Quality; applicable detection limits; and quantitative targets for precision, accuracy, and completeness, for both the field laboratory and the offsite laboratories.

Specific numerical targets for intralaboratory precision and field sampling precision have not been developed. The following general guidance will be used for evaluation. Good intralaboratory and field sampling precision are assumed if the criteria in Table 4-1 are met. Fair intralaboratory and field sampling precision are indicated by agreement within two times the criteria presented in Table 4-1, while poor precision is indicated when the difference between data points is consistently greater than twice the criteria specified in Table 4-1.

Quantitative DQOs for representativeness and comparability are not appropriate; instead, qualitative statements associated with the methods used and compliance with accepted procedures for data collection activities are used to assess these two criteria. Table 4-1 includes the analysis methods that were used during the test. As indicated in the table, method modifications/changes were necessary to improve the completeness and representativeness of the radiochemistry analyses. These changes and modifications are discussed in Section 4.5.

To assess compliance with the quantitative targets of precision, accuracy, and completeness, quality control samples are collected and analyzed both in the field and in the laboratories.

4.2 QUALITY CONTROL SAMPLES

Quality control samples collected to evaluate field and laboratory procedures included the following sample types:

- Field blank samples (2) to assess possible sample container, and preservative contamination for water samples
- Trip blank samples () to assess airborne contamination during shipping and handling of VOC containers

- Field duplicate samples (15) to assess the reproducibility of sampling both soils and recycled water
- Field split samples (15) to assess the interlaboratory precision of the analyses.

In addition to the quality control samples collected in the field, both the primary laboratory, Roy F. Weston, and the laboratory analyzing the split samples, Data Chem Laboratories, analyzed method-specific quality control samples that included, but was not limited to, the following:

- Laboratory duplicate samples of both water and soil samples to assess the reproducibility of the laboratory analyses
- Matrix spike samples and matrix spike duplicate samples for soil and water samples to assess the accuracy of the analyses and identify matrix interferences
- Laboratory control samples (blank spike samples) for water and soil samples to assess the accuracy of the analyses
- Preparation blank samples (laboratory blank samples) for water and soil samples to identify and quantitate contamination introduced during sample preparation and handling
- Instrument blank samples (instrument backgrounds for radiochemical analyses) to identify and quantitate contamination introduced during sample analysis
- Calibration verification samples (continuing calibration check samples) to ensure that the instrument performance is consistent with the initial calibration.

4.3 DATA VALIDATION

The data generated by both the Roy F. Weston Laboratory and the Data Chem Laboratories were subjected to the requirements of the WHC statement of work, which required validation of sample data at Level A with selected samples (at least 10%) validated at Level B or for radiochemistry validated in accordance with the procedures provided by WHC. Data validation of analyses for metals and VOCs were conducted in accordance with the Level A and B guidelines presented in Chapter 2.0 of WHC-CM-5-3 (WHC 1990).

Level A Review Requirements:

Requested versus reported analyses
Analysis holding times

Level B Review Requirements:

Requested versus reported analyses
Analysis holding times
Matrix spike/matrix spike duplicate analyses

Surrogate recoveries
Duplicate analysis
Analytical blank analysis

For metals and VOCs, a total of 154 samples were evaluated according to Level A criteria, while 133 samples were evaluated according to Level B criteria.

Data validation of radiochemical analyses provided by Roy F. Weston Laboratory through its subcontractor Teledyne were validated according to the Level C guidelines presented in *Data Validation Procedures for Radiochemical Analyses*, WHC-SD-EN-SPP-001 (WHC 1993). A total of 160 samples were validated according to the Level A criteria specified above with an additional 127 samples validated in accordance with the above referenced procedures.

The following data validation codes have been used and are included on the data tables presented in this report.

- < Indicates that the constituent was analyzed but not detected.
- U Indicates that the constituent was detected in the sample and either in the associated field blank sample, trip blank sample, or laboratory blank sample. Because the concentration of the constituent reported in the sample may reflect contamination introduced either during field collection or analysis, the data are interpreted to mean that the constituent was **not** detected at the concentration shown.
- U/J The constituent is considered not detected, and the data are considered estimated for one or more of the following reasons: analysis completed outside holding times, quality assurance targets for matrix spike samples, matrix spike duplicate samples, laboratory duplicate samples, laboratory control samples, continuing calibration verification samples, surrogate spiking compounds, internal standard recoveries, carrier recoveries, or tracer recoveries were not met.
- J The constituent is present in the sample, but the result reported is an estimated concentration/activity for one or more of the following reasons: analysis completed outside holding times, quality assurance targets for matrix spike samples, matrix spike duplicate samples, laboratory duplicate samples, laboratory control samples, continuing calibration verification samples, surrogate spiking compounds, internal standard recoveries, carrier recoveries, or tracer recoveries were not met. Although data evaluations and conclusions should not be drawn from a single estimated result, a body of estimated data can still be used in data evaluation, interpretation, and regulatory decision making.
- R The data are considered unusable because either field sampling or laboratory quality control deficiencies were sufficiently severe that neither the absence, presence, or relative concentration/activity of the constituent cannot be determined from the data provided. These data should not be used for decision-making purposes. No conclusions should be drawn from the data without supporting information or corroborating data.

Data validation codes based on the Level B evaluation discussed above have been included on the metals and VOC data shown in Tables 3-4, 3-5, 3-15, 3-19, 3-25, and 3-43. Data validation codes based on the Level C evaluation discussed above have been included on the radiochemical data shown in Tables 3-15, 3-25 and 3-34.

4.4 COMPARISON OF THE DATA TO THE DATA QUALITY OBJECTIVES

The following section summarizes the findings of the data review and validation with respect to the DQOs specified in the QAPjP. A more detailed discussion of the findings of the data validation and reasons for qualification of selected results is provided in the data validation reports prepared for each data package.

4.4.1 Precision

Interlaboratory precision, field sampling precision, and intralaboratory precision (confirmation of results) were evaluated using the results of laboratory duplicate samples, field duplicate samples, and field split samples. The following assessment of interlaboratory, field sampling, and intralaboratory precision is based on the precision targets previously discussed.

4.4.1.1 Intralaboratory Precision. In conjunction with each group of samples received, Roy F. Weston/Teledyne was required to select one or more samples for laboratory duplicate analyses. The minimum frequency of laboratory duplicate analyses was specified as 1 per batch of samples processed or 1 in 20 samples processed, whichever is greater. The acceptance criteria for laboratory duplicate analyses are shown in Table 4-1. The results of the laboratory duplicate analyses are discussed in the data validation memorandums provided with the laboratory data. Of the results generated, approximately 90% of data met the precision targets specified in Table 4-1 and in the validation guidelines.

4.4.1.2 Field Sampling Precision. A total of 15 samples were collected as field duplicate samples, three from feed material, recycled water, and the three process streams, process oversize, sand product, and fines. These samples were labeled to conceal their identity (e.g., HVFFD-001 for the field duplicate of sample HVFSL-005) and were submitted to Roy F. Weston/Teledyne for the same analyses as the field samples.

No specific numerical precision targets have been established for field duplicate samples. The analysis of field duplicate samples is expected to be less precise than the analysis of laboratory duplicate samples because the field duplicate analysis includes errors associated with field sample collection, preparation, and handling as well as the laboratory errors. As shown in Table 4-2, for this project, 87% of the field duplicate results for metals and the six detected radionuclides met the precision criteria established for laboratory data.

With respect to the VOC data, the results of the field duplicate analyses confirmed the absence of 32 of the 33 VOCs monitored. Methylene chloride was detected in the two of the three field duplicates. However, like the sample data, the methylene chloride results for the field duplicates were classified as undetected due to the presence of methylene chloride in the analytical blanks processed with the samples. Therefore, the VOC data showed 100% agreement between the field samples and the field duplicates.

4.4.1.3 Interlaboratory Precision. Each of the 15 samples discussed above were also prepared as field split samples. The field split samples were collected in the same manner as the field duplicate samples but instead were submitted to an independent laboratory, Data Chem Laboratories of Salt Lake City, Utah. Like field duplicate samples, no numerical criteria have been established for the evaluation of field split samples. The comparison of the analysis results for field split samples is expected to demonstrate less precision than laboratory duplicate samples because field split analyses include errors associated with the field sample collection, preparation, and handling; the primary laboratory's analyses; and the "split" laboratory's analyses.

As shown in Table 4-3, for this project, over 70% of the field split sample analyses for the metals and radionuclides met the criteria established for laboratory duplicates. Of the remaining data points, half were within a factor of two of each other. These data demonstrate good agreement for over 85% of the data collected. With the exception of two data points (iron in sample HVRWA-1 and uranium in HGAOSL-2), the remaining data points agreed within factors between 2 and 5. For the three field split samples submitted for VOCs, only 2-butanone was detected (2 $\mu\text{g/L}$). This result is less than the quantitation limit for both laboratories, and the detection of 2-butanone at this low concentration is considered acceptable agreement between the laboratories.

4.4.2 Accuracy

Interlaboratory accuracy was evaluated using the results of matrix spike samples, matrix spike duplicate samples, surrogate spiking compounds, tracer recoveries, and laboratory control samples. Surrogate spiking compounds and tracer recoveries were evaluated for each sample. Matrix spike samples and laboratory control samples were prepared by Roy F. Weston/Teledyne at a minimum frequency of 1 matrix spike and laboratory control sample per batch of samples processed or 1 in 20 samples processed, whichever is greater. The acceptance criteria for these quality control samples are presented in the associated data validation guidance documents. The results of the evaluations of the matrix spikes, laboratory control samples, tracer recoveries, and surrogate spiking compounds are discussed in the data validation memorandums provided with the laboratory data. Of the results generated, approximately 85% of data met the precision targets specified in Table 4-1 and in the validation guidelines.

Two trends were noted when reviewing the quality control data for accuracy prepared by Roy F. Weston/Teledyne. First, virtually all of the data qualified based on assessments of accuracy were due to poor matrix spike recoveries. Specifically, all the data generated for several metals the recycled water samples from the verification run were coded as qualified or unusable. The poor matrix spike recovery was a result of the very high suspended solids concentrations present in the sample selected for the matrix spike, HVRWA-001. It is likely that if one of the six samples collected after the recycled water quality improved had been selected as the matrix spike, these data would not have been qualified.

Second, the analysis of the matrix spikes for uranium-238 in soil samples by alpha isotopic analysis consistently showed low recoveries. Rather than using an aqueous solution to spike the soils, the laboratory was directed to use a solid material, a National Bureau of Standards referenced pitchblende ore for the spiking material. Selected samples selected for alpha isotopic analyses also showed low tracer recoveries. The same spiking material was used in the preparation of the laboratory control samples, which generated acceptable recoveries. It is

spectrometry analysis is much more independent of chemical matrix effects (it does not require sample dissolution), conducting all uranium analyses by gamma spectrometry may produce more quantitative data.

4.4.3 Representativeness

The representativeness of the data is controlled through the selection of sampling locations and the use of sampling and analysis methods that are documented, accepted, and approved by various state and federal government agencies.

Sampling methods and the location of sample collection points used for this project were specified in the QAPJP (ART 1994a) and the Test Procedure (ART 1994b), which were approved by WHC prior to initiation of the test. The procedures are based on sampling methodologies described in *Environmental Investigations and Site Characterization Manual*, WHC-CM-7-7 (WHC 1988), and EPA Region IV *Standard Operating Procedures and Quality Assurance Manual* (EPA 1991). Modifications to the above referenced procedures are discussed in Section 4.5.

Methods of analysis, reporting units, and detection limits used for the test were specified in the QAPJP and approved by WHC prior to initiation of the test. The methods specified for the analysis of metals and VOCs were approved EPA methods from *Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods* (EPA 1990). Methods for the analysis of radionuclides were selected from procedures previously approved by WHC via contract with Roy F. Weston, Inc. The modification to the method for analysis of total uranium in water (PRO-032-9) and substitution of Method PRO-042-5 (gamma spectroscopy) for Method PRO-032-9 are discussed in Section 4.5.

4.4.4 Completeness

The total number of analyses that met the indicated quality control requirements divided by the total number of analyses that were validated multiplied by 100 is equal to the percent completeness. Precision and accuracy objectives established for this project required 80% completeness. As specified above, 90% of the data validated met the requirements for precision and 85% of the data validated met the requirements for accuracy. Only 1% of the data was classified as unusable.

4.4.5 Comparability

Comparison of the results to previous work was facilitated by the use of representative methods of collection and analysis and the reporting of the data in units that are accepted as standard convention for the constituents monitored. The detection limits reported were consistent with the methods used and were substantially lower than the test performance criteria.

4.5 EVALUATION OF FIELD LABORATORY DATA

A significant component of the pilot test was the use of the field XRF laboratory and the evaluation of the data produced. The Spectrace 9000 used during the pilot test was capable of being calibrated to the site-specific matrix and providing a sensitivity sufficient to monitor the process products for the key constituent of concern in the North Process Pond, uranium-238. A detection limit evaluation performed with this instrument indicated a minimum detectable concentration of 25 mg/kg could be obtained with a total counting time of 6 minutes. Sensitivity could be improved by extending the counting time. The total instrument time necessary to produce a 6-minute count is approximately 10 minutes.

The XRF is significantly affected by the particle size, homogeneity, and moisture present in the samples. These factors require that each sample be dried and ground to a fine powder prior to analysis. The time necessary to dry, crush, and grind individual samples varied from 20 to 30 minutes for process oversize samples up to a day for samples of the fines (these samples were oven dried overnight).

The comparability of the instrument has been evaluated by comparing the data for copper and total uranium generated by the XRF to the generated by Roy F. Weston/Teledyne. The data comparison is shown in Table 4-4.

For samples where the constituents were detected in both the field laboratory and in the offsite laboratory, a relative percent difference (RPD) was calculated. The average RPD for copper was 22%, while the average RPD for uranium was 29%. Approximately 80% of the detected copper concentrations reported by the field and offsite laboratories were within an RPD of 35%, which is the limit applied to laboratory duplicates. For uranium, 65% of the data met the laboratory duplicate criteria. Only 2% of the copper data and 4% of the uranium data showed differences between the two laboratories greater than a factor of two. These precision data are very similar to the interlaboratory precision results reported for the field splits (analyzed by two the commercial laboratories) in Section 4.4.1.3.

4.6 DEVIATIONS FROM THE TEST PROCEDURE

Several deviations from the Test Procedure were necessary to improve the completeness and representativeness of the data collected as well as facilitate timely completion of the test.

4.6.1 Operations Changes

4.6.1.1 Prescreening. The procedures specified in the Test Procedure indicated that the plant feed would be weighed and staged into three discrete piles. Subsequently, the feed would be introduced to the plant without the need for weighing because when the material in the staged pile was exhausted, the complete mass of the pile would be assumed to have been feeding to the plant. However, after mobilization onsite two issues were noted. Recovery of all material placed in a prestaged pile was unlikely based on the size of the loader and the roughness of the base of the pond. Efforts to recover all the material in a prestaged pile would have required the operator to scrape the pond floor, thereby including cobbles in the plant feed. Inclusion of coarse material as a result of scraping would jam and possibly damage the feed hopper.

Consequently, the decision was made to prescreen excess material and stage it in one pile to minimize losses during feeding of the plant.

4.6.1.2 Preprocess Weighing. Delays occurred in obtaining a rubber tire loader of the appropriate size to feed the mobile dry screening unit for prescreening of the plant feed to less than 50 mm. When the loader became available, the time available to prescreen the feed material was limited. During the first one and one-half days of prescreening, the loader was weighed to obtain a tar weight, and each bucket of gross feed was weighed to determine the mass of material prescreened. The mass of plant feed (< 50 mm) was also weighed. Because of the consistency of the weights, an average gross feed weight per bucket and an average plant feed weight per bucket were calculated. Except for spot checks, the number of buckets was counted and multiplied by the average bucket weight to determine the mass of material prescreened as well as the mass of plant feed (< 50 mm). The mass of gross oversize (> 50 mm) was determined by calculating the difference between the gross feed and the plant feed.

4.6.1.3 Feed and Products Weighing. Prior to the pretest, the area designated for feed material weighing was prepared by clearing the large cobbles and rocks and placing a bed of sand at the location of each of the four scales. During the pretest run, ART personnel directed the loader operator to drive onto the scales. The weight was read and the bucket was emptied into the feed hopper. At the end of the pretest, ART personnel attempted to balance the mass of material that was processed. Unfortunately, the sum of the mass of plant products, the process oversize, clean sand, and fines was not equal to the measured weight of feed material. Upon review of the data, the variation in the weights without a corresponding variation in the size of the bucket loads indicated an error in the measurement of the bucket weight. Because of the large size of the loader tires and the loader itself, it was very difficult for the loader operator to position himself on the center of the scales each time the loader was weighed. It was noted by field personnel that minor differences in position could cause differences of hundreds of pounds in the measured weight. Although the variation noted was not a large percentage of the total weight of the loader and feed soil, because the weight of the feed material was calculated by difference, the variation in the measured mass of feed material was significant. For subsequent runs, the procedure was changed so the loader operator would position the loader close to the scales. ART personnel would then manually position each of the four scales immediately in front of each tire and then the loader operator was directed to drive onto the center of the scales. Based on the mass balance of plant products developed for the three subsequent tests, this procedure produced substantially more consistent weights than the previous method.

4.6.1.4 Recycled Water Treatment. The equipment specifications presented in the Test Procedure indicated that addition of water treatment flocculants would occur in the overflow from the hydrocyclone. However, bench testing of the coagulants at PNL prior to the pretest indicated that the contact time between the suspended particulates and the selected coagulant was not sufficient to achieve good separation in the settling tank. The decision was made to add the coagulant in the sump below the dewatering screen. After minor difficulties with the coagulant delivery pump were resolved, the change in procedure appeared effective as indicated by the quality of the recycled water in the final six sampling events of the verification run.

4.6.1.5 Recycled Water Handling. The Test Procedure originally specified that after the verification and replication runs, the recycled water would be pumped to a holding tank pending final treatment and disposal. However, during the operation of the pretest and verification run, it became evident that the water treatment system was adequate to produce recycled water quality

that could be reused on an ongoing basis. Because the uranium carbonate run was scheduled last, the low levels of constituents of concern observed during the verification and replication runs were insignificant compared to the increase in dissolved constituents expected during the uranium carbonate run. Also, continued operation of the plant with recycled water is a better reflection of full-scale operating conditions than emptying the plant after each run. Therefore, to minimize the mass of waste generated and the use of potable water, the plant was not emptied of recycled water between runs. This procedure reduced the amount of waste water generated by approximately 5,000 gal.

4.6.1.5 Recycled Water Management. The Test Procedure originally required ART to manage the recycled water by forced evaporation of the water and collection of the secondary waste/sludge for characterization and disposal. Upon mobilization of the boiler system and an operational test using clean water, WHC determined that forced evaporation could not be conducted safely with the available equipment. WHC instead directed ART to transfer the recycled water remaining in the plant to the fractionation tanks onsite. WHC agreed to be responsible for subsequent management and disposal of the recycled water.

4.6.1.6 Mass of Material Processed. The mass of material required to be processed during the pretest, verification, and replication runs was "up to 300 tons." Based on previous data, ART anticipated that the gross feed would contain approximately 40% gross oversize (> 50 mm). On this basis, ART targeted 175 tons of feed as the mass of material to be processed through the plant. ART produced 199 tons of feed material, believed to be 24 tons excess. Based on the review of the data conducted for the report, it appears that only about 25% of the prescreening feed was gross oversize. Therefore, the calculated mass of materials prescreened was 273.2 tons, 91% of the target. During the verification run, the problems with the feed hopper required manual control of the feed rate. The field estimated rate was less than the 16.9 tons/h feed weight calculated from the field data. This resulted in processing of 79.8 tons, rather than the 70 tons specified in the Test Procedure. During the replication run, the feed rate calculated in the field overestimated the true feed rate of 9.1 tons/h. Therefore, only 52.1 tons of materials was processed. A similar situation occurred during the uranium carbonate run. Based on a revised estimate of the gross oversize at 25%, ART prescreened 60 tons of uranium carbonate material, which was 10 tons in excess of the original target mass of 50 tons as specified in the Test Procedure. However, the fraction of gross oversize in the uranium carbonate materials was only 17.6%. Therefore, only 75 of the target 80 tons of uranium carbonate material was prescreened. The Test Procedure also allowed for processing of 10 tons of uranium carbonate material as a process testing cycle for the uranium carbonate run. Based on the results of the previous runs and the hydrocyclone configuration selected, the ART Field Manager with the approval of the WHC Project Manager determined that a process testing cycle was not necessary and the operations progressed directly into the 40-ton uranium carbonate run. For the pretest, verification, replication, and uranium carbonate runs, the total tons of plant feed processed were 208.3 tons, which represents 97% of the target mass of 215 tons.

4.6.1.7 Uranium Carbonate Attritioning Cycle. As discussed in Section 3.4.5, after completion of the first attritioning cycle, field personnel observed visible green material/flakes in the sand. Measurements of total activity by use of a GM counter confirmed that a substantial concentration of radioactive material remained in the sand. Further, the ART process engineer had observed that the sand density from the hydrocyclone underflow to the attritioner was lower than desired. However, due to the large mass of oversize, the wet screen limited the feed rate, and the feed rate could not be increased to a level high enough to produce the desired hydrocyclone

underflow density. For these two reasons, the decision was made to feed the sand back into the plant at a rate sufficient to achieve good performance by the attritioner. After this second attritioning cycle, a third cycle was conducted to determine if additional residence time in the attritioner could further reduce the measured activity in the sand fraction. At the conclusion of the third attritioning cycle, the washing cycle was conducted as specified in the Test Procedure.

4.6.2 Changes in Sampling Procedures

4.6.2.1 Preprocess Sampling of Gross Oversize. As discussed above, all the feed material for the pretest, verification, and replication runs was prescreened at one time. Therefore, only one pile of gross oversize material was created, not the three piles as suggested in the Test Procedure. As such, the three samples of gross oversize material collected for washing were not collected as composites from each of three piles; instead, the three samples were collected as discrete grab samples from the one pile of gross oversize produced. During washing of the three samples, an insufficient mass of washed solids was generated from each of the three samples to submit for analysis. Consequently, the washed solids from the three analyses were combined into one composite sample and the composite sample was submitted for analysis.

4.6.2.2 Particle Size Analysis of the Fines. As indicated earlier, the location of delivery of the coagulant to the process stream had to be moved from the discharge pipe carrying overflow from the hydrocyclone to the dewatering screen sump. Therefore, as the particles passed from the wet screen through the hydrocyclone, coagulation of the fines had already begun to occur. The collection point for samples of the fines designated for particle size analysis was originally located on the overflow of the hydrocyclone. With the modifications to the water treatment system, the coagulant was added prior to the hydrocyclone separation. Collection of samples for particle size distribution and chemical analysis of the fines would not have produced useful data because the particle size distribution had been altered by coagulation before a sample of the hydrocyclone overflow could be collected. For this reason, collection of the fines for chemical analysis of the particle size fractions was eliminated. The data from the particle size analysis of the fine fractions of the feed material were used in the data evaluations instead of the fraction data from the sludge.

4.6.2.3 Final Feed Sample for the Replication Run. The last feed sample collected during the replication run was collected from the feed hopper and not from the bucket of the loader. Although the concentration/activities of the constituents monitored did not appear affected by the difference in sampling location, the particle size distribution of the sample differed when compared to the particle size distribution of the other feed samples from the pretest, verification, and replication runs that were subjected to particle size analysis. It is not clear whether the difference in particle size distribution of the feed sample reflects the effects of gravity separation in the feed hopper or a true difference in the feed material as the feed pile became exhausted.

4.6.2.4 Collection of Process Oversize Samples. The Test Procedure indicated that samples of the process oversize could be collected either from the discharge directly into a bucket or shovel or the samples could be collected from the pile of process oversize material. During the pretest run, field observations indicated that the velocity of the falling particles made direct collection using a bucket or shovel impractical. The decision was made to collect the samples from the pile of process oversize as the material accumulated. However, upon review of the fraction analysis of the feed material and the process oversize, it was determined that sampling from the

pile generated samples that were not representative of the particle size distribution in the feed. For this reason, a sampling device constructed of a long-handled fishing net lined with a polyethylene garbage bag was assembled to collect the process oversize material as it fell from the wet screen. Based on the data from the subsequent three runs, the modified device was effective in collecting process oversize samples whose particle size distribution was consistent with the particle size distribution of the feed.

4.6.2.5 Sampling of Makeup Water. According to the Test Procedure, four samples of makeup water were to be collected, one pair of samples prior to the pretest run and one pair of samples prior to the replication run. The first pair of samples was collected as specified. However, because the recycled water was not removed from the plant prior to either the replication or the uranium carbonate run, only small quantities of makeup water were required. Because the quality of the makeup water would not represent the initial water quality in the plant prior to initiating the replication run and uranium carbonate run, a sample of recycled water circulating in the plant was collected instead. Just prior to initiating each run, ART operated the plant for a short period with just recycled water to adjust process valves and pump pressures. The period was referred to as the water balance. During the water balance of the plant but prior to introduction of soil for the replication run and again for the uranium carbonate run, a single sample of recycled water was collected to establish the baseline water quality prior to each of the runs.

4.6.3 Changes in the Laboratory Analysis Procedures

4.6.3.1 Total Uranium Analysis of Washed Gross Oversize. The Test Procedure called for total uranium analysis of one sample of the washed gross oversize collected during preprocessing activities. The sample was designated for analysis by gamma spectroscopy at PNL. After conversations with PNL staff, it was determined that the size of the individual particle would be limited to 75 mm and that without sample preparation to reduce the particle size, the result would produce only estimated results for uranium. To produce data more quantitative in nature, ART personnel selected several particles from each of the three samples of washed gross oversize, initial fractured the particles with a hammer, stage crushed the fractured particles, and subsequently ground them. The prepared samples were then submitted to the offsite laboratory for uranium analysis at DQO Level V.

4.6.3.2 Analysis of Total Uranium in Water Samples. The procedures included in the Test Procedure for the analysis of total uranium specified a chemical laser fluorescence technique. The procedure prepared by the laboratory specified that water samples should be filtered prior to analysis. This step would preclude analysis of any metals bound in the suspended solids anticipated to be present in the recycled water. Further, this procedure is contrary to EPA guidance on sample analysis of metals in groundwater and soil samples. At the direction of ART, Teledyne, through the contractor Roy F. Weston, modified the sample preparation procedures to include a sample digestion step EPA Method 3010 prior to sample filtration in an effort to capture uranium bound in the suspended solids. Also, during sample analysis of the water samples, Teledyne noted poor recoveries of the internal standard and of the matrix spike samples. A severe matrix effect was suspected. The high levels of iron in the samples were thought to be a contributor to the problem. To overcome the interference, the laboratory instituted a procedure that diluted the sample approximately 30-fold prior to analysis. This improved the recovery of the internal standard and matrix spikes. However, the quantitation

limit was elevated to 0.15 $\mu\text{g/L}$. This increase in detection limit was not significant because uranium was consistently detected in the samples at concentrations above the detection limit.

4.6.3.3 Analysis of Total Uranium in Soil Samples. As indicated above, Teledyne experienced severe matrix interferences with their laser fluorescence method for determining total uranium. The matrix interference proved insurmountable and Teledyne, with concurrence from ART and WHC, changed the method of analysis to PRO-042-5, which is the gamma spectrometry technique specified in the Test Procedure for analysis of gamma-emitting nuclides.

4.6.3.4 Fraction Analysis of Small Fractions. According to the Test Procedure, ART was not required to analyze fractions that constituted less than 1% of the particle size distribution from a product sample. Instead, the material was to be combined with the next larger or next smaller fraction as appropriate. During the test, it became apparent that by combining all fractions less than 1% with a larger or smaller particle size fraction, valuable information would be lost. For example, if the 0.045- to 0.075-mm fraction of the initial sample of clean sand was 0.5%, it was designated to be combined with the 0.075- to 0.15-mm fraction of the initial sand. Therefore, the results would reflect the contaminant load for the combined fraction 0.045-0.15 mm. Because two samples of each of the process products were collected for fraction analysis (initial and final sample), there were times when combining a sample of a particular particle size (i.e., 0.045-0.075 fraction from the initial clean sand) with the sample of the same particle size from the other fractioned sample (i.e., 0.045-0.075 fraction from the final clean sand) would provide sufficient sample for analysis. In these cases, the two samples were composited to provide data for the fractions present at less than a 1% distribution. This change in procedure resulted in analysis of 10 samples that would not have been analyzed by the previous procedure.

4.6.3.5 Particle Size Analysis. The American Society for Testing and Materials method specified in the test procedure was modified to allow ART personnel to generate sufficient sample mass to submit to the onsite as well as offsite laboratories. Generally, several hundred grams of material were required by the laboratories to complete field XRF analyses, metals analyses, and total uranium analyses by gamma spectrometry. This necessitated ART to subject from 5 to 10 kg of material to particle size distribution analyses. The ASTM method was modified to allow ART personnel to manually wet sieve the particle size fractions rather than use an automated shaker. The mass balance of each of the particle size distributions and percent recovery of the sieved material were calculated to support the adequacy of the modified procedure. Further, the Test Procedure specified the use of a 13.2-mm sieve. During mobilization, ART was unable to order a sufficient number of this sieve size to complete the particle size analyses. A 12.5-mm sieve was substituted for the 13.2-mm sieve. The change in sieve size did not affect the data evaluation or data interpretation discussed in Chapter 3.0.

4.7 DATA EVALUATION

After compilation of the database, the body of data was reviewed for agreement between related interlaboratory and intralaboratory data, consistency of trends between constituents, and preparation of the mass balances discussed in Chapter 3.0. The following paragraphs address inconsistencies in the database.

4.7.1 Uranium

Interlaboratory agreement between results can be evaluated for certain radiochemical analyses. For example, the uranium-238 to uranium-234 ratio as well as the uranium-238 to uranium-235 ratios are known quantities that have narrow ranges in variation that are dependent on the waste stream monitored. Because the gamma scan also monitors for thorium-234, which is used to calculate uranium-238 concentrations, when samples were subjected to both isotopic uranium analysis and gamma scans, the data could be checked to compare the activities of uranium-238 detected by each method and to compare the isotopic uranium abundances as determined from the isotopic uranium data.

Based on this data review, it appears that in some cases the isotopic uranium analysis underestimated the activity of uranium present when compared to the gamma scan. This problem was most prevalent in the analysis of the fines from the uranium carbonate run. For the two samples that had both sets of analyses, the gamma scan results detected on average twice as much uranium as the isotopic uranium analysis. This phenomena may be a result of the incomplete leaching/digestion of the sludge for the isotopic uranium analysis. It should be noted that the fines samples contained an elevated concentration of organic material and water treatment flocculants, as well as a higher concentration of metals; any of these factors is likely to result in incomplete leaching of the uranium and to generate lower recoveries.

4.7.2 Data Outliers

During evaluation of the fraction analysis data from the uranium carbonate run, it was observed that sample HGAF2SL-FRCF had much lower concentrations of copper and uranium than would be expected based on (1) the particle size of the sample, (2) the concentrations of these constituents in the same particle size from the initial feed sample (HGAF1SL-FRCF), and (3) the concentrations of these constituents in the samples from the next larger and next smaller fractions of the final feed sample. Based on a review of the field records, there was no evidence that the sample had been mislabeled. However, on the weight of the constituent data, the data for this sample were excluded from the data evaluation. The average concentration/activities of copper and uranium for the two samples from the next larger and next smaller particle size were used as surrogate values.

4.8 DATA HANDLING AND MANAGEMENT

Field and laboratory data collected by ART and WHC for the test were managed in accordance with the procedures specified in the QAPjP (ART 1994a).

All samples collected and submitted to the offsite laboratories have been assigned a Hanford Environmental Information System (HEIS) number to facilitate inclusion of the data into the database managed by WHC for the 300-FF-1 Operable Unit.

As specified in the Test Procedure (ART 1994b), the laboratory data were tabulated for use in the report. Because the test performance criteria for uranium-238 were expressed in picocuries per gram and analyses of the majority of the samples were conducted for total uranium expressed in milligrams per kilogram, it was beneficial to convert values for total uranium (mg/kg) to uranium-238 (pCi/g). Two assumptions are required to complete this

conversion. First, uranium-234 is assumed to be in secular equilibrium with uranium-238 and, therefore, the activity of uranium-234 must by definition be equal to the activity of uranium-238. This assumption appears valid since a brief review of the raw data provided for the samples analyzed by alpha spectrometry indicated that the uranium-234 activity was similar to the activity of uranium-238. The second assumption requires that the activity of uranium-235 approximately 7% of the activity of uranium-238 for the site. This is a reasonable assumption for the site since the uranium materials presented are reported to be either natural uranium or slightly enriched uranium used for fuel rods. This relative ratio of uranium-235 to uranium-238 was also qualitatively confirmed by the alpha spectrometry analysis discussed in Chapter 3.0. Using these assumptions and the specific activities of the three uranium isotopes, a conversion factor between milligrams per kilogram and picocuries per gram for each isotope is calculated.

$$\text{Uranium-238 pCi/g} = \text{uranium-total mg/kg} \times 2.97$$

$$\text{Uranium-235 pCi/g} = \text{uranium-total mg/kg} \times 0.03$$

$$\text{Uranium-234 pCi/g} = \text{uranium-total mg/kg} \times 0.00015$$

The combined factor for converting uranium-238 data to total uranium data is simply the sum of the three factors. Therefore, a conversion factor of 3 is used to convert total uranium results to uranium-238 activities.

Also, in order to facilitate data comparisons between the large volumes of data generated for each of the fractions analyzed during the tests, it was necessary to calculate average concentrations/activities of constituents. However, in some cases constituents were reported from samples within the same process stream to have concentrations/activities that varied just above the laboratory detection limit and were at times below the limit. To facilitate comparisons between data sets having both detected and "undetected" results, the averages and standard deviations of the means were calculated using the convention that the concentration of a constituent reported to be less than the detection limit would be defined as equal to one-half the detection limit. Likewise, when the "load" or mass contribution of a "undetected" constituent was calculated, the calculation was performed by taking the product of the mass distribution times one-half the reported detection limit.

Table 4-1. Analytical Parameters, Detection Limits, and Precision and Accuracy Requirements. (sheet 1 of 2)

Category of Analysis	Analyte of Interest	Analytical Level ^A	Analytical Method	MDL or PQL (Soil) ^B	Precision (Soil) ^C	Accuracy (Soil) ^C	MDL or PQL (Water) ^B	Precision (Water) ^C	Accuracy (Water) ^C
Radionuclides	Gamma Spectroscopy	V	PRO-042-5	g	±35 ^I	30-105	g	±35 ^I	30-105
	Total Uranium	V	PRO-042-5 (Soil) PRO-032-89 (Water)	1 ug/g	±35 ^I	30-105	0.1 ug/L	±35 ^I	30-105
		II	X-Ray Fluorescence	25	±35 ^I	40-160	---	---	---
	Uranium-235	V	EP-70, EP-71, EP-5, PRO-052-32, RL-2322 (W,S) ^F	1 pCi/g	±35 ^I	30-105	1 pCi/L	±35 ^I	30-105
	Uranium-238	V	PRO-062-110	1 pCi/g	±35 ^I	30-105	1 pCi/L	±35 ^I	30-105
Metals ^D	Aluminum	III	6010 ^E	4.5	±35	75-125	45	±20	75-125
	Antimony	III	6010 ^E	3.2	±35	75-125	32	±20	75-125
	Beryllium	III	6010 ^E	0.3	±35	75-125	3	±20	75-125
	Cadmium	III	6010 ^E	0.4	±35	75-125	4	±20	75-125
	Chromium	III	6010 ^E	0.7	±35	75-125	7	±20	75-125
	Copper	III	6010 ^E	0.6	±35	75-125	6	±20	75-125
		II	X-Ray Fluorescence	75	±35	60-140	---	---	---
	Iron	III	6010 ^E	0.7	±35	75-125	7	±20	75-125
	Lead	III	7421 ^E	0.1	±35	75-125	1	±20	75-125
	Manganese	III	6010 ^E	3	±35	75-125	30	±20	75-125
	Mercury	III	7470/7471 ^E	0.02	±35	75-125	0.2	±20	75-125
	Nickel	III	6010 ^E	1.5	±35	75-125	15	±20	75-125
	Silver	III	6010 ^E	0.7	±35	75-125	7	±20	75-125
	Zinc	III	6010 ^E	0.2	±35	75-125	2	±20	75-125
Volatile Organics (VOAs) ^D	1,2-Dichloroethene	III	8240 ^E	N/A	N/A	N/A	5	D	D
	Methylene Chloride	III	8240 ^E	N/A	N/A	N/A	5	D	D
	Tetrachloroethene	III	8240 ^E	N/A	N/A	N/A	5	D	D
	Trichloroethene	III	8240 ^E	N/A	N/A	N/A	5	D	D
Other Analyses	TCLP	III	1311 ^E	N/A	N/A	N/A	N/A	N/A	N/A
	pH & Temp (H ₂ O)	III	H	N/A	N/A	N/A	N/A	N/A	N/A
	Mass	III	D421, D2216, D2217	N/A	N/A	N/A	N/A	N/A	N/A
	Percent Moisture	III	D2216, D2217	N/A	N/A	N/A	N/A	N/A	N/A
	Dry Sieving	III	D421, D422, E-11 ^J	N/A	N/A	N/A	N/A	N/A	N/A

Table 4-1. Analytical Parameters, Detection Limits, and Precision and Accuracy Requirements. (sheet 2 of 2)

Notes:

- A Analytical Levels are as defined in Section 4.3.1 of Data Quality Objectives for Remedial Activities: Volume I, Development Process (EPA, 1987).
- B MDL refers to the Method Detection Limit and are provided for PCB analyses. PQL refers to the Practical Quantitation Limit and are provided for the Volatile Organics (VOAs). IDL refers to the estimated Instrument Detection Limit and is provided for the inorganic analyses (metals). PQLs are provided for all other categories, and represent maximum values that can be reliably achieved by analytical laboratories under routine normal conditions. Unless otherwise specified, all inorganic soil values are expressed in mg/kg, and all organic soil values are expressed ug/kg. All values for water are expressed in ug/L unless otherwise noted.
- C The ranges provided shall be considered maximum values that can be reliably achieved by the laboratories under routine normal conditions. Precision is expressed as Relative Percent Difference (RPD); accuracy is expressed as percent recovery (%R).
- D Methods, IDLs, precisions and accuracies are as specified for inorganic analysis. For Volatile Organics and Pesticides/PCBs, the EPA has designated representative compounds to be used as spikes and has defined precision and accuracy numbers for these compounds. If the spiked compounds meet the criteria outlined by the EPA, the other compounds analyzed also meet the criteria.
- E Methods specified are from Test Methods for Evaluating Solid Waste (EPA 1990).
- F Methods specified are from WHC contracts with Roy F. Weston Inc. (methods with prefix PRO- and RL-).
- G Detection limits will vary with each constituent (examples: Co-60 = 0.05 pCi/g; Cs-137 = 0.1 pCi/g; and Ra-228 = 0.2 pCi/g).
- H Parameter shall be measured in the field in compliance with EII 5.8 "Groundwater Sampling" (WHC 1988).
- I For radiological analysis Relative Percent Difference between the sample and duplicate analysis must be within the control limits of $\pm 35\%$ for results $> 5X$ the LLD. A control limit of $\pm 2X$ the LLD is applied if one or both of the sample values are $< 5X$ the LLD. If both values are $< LLD$, no control limit is applicable.

Table 4-2. Comparison of the Laboratory Results for Process Samples and Field Duplicate Samples Analyzed by Roy F. Weston/Teledyne. (sheet 1 of 2)

Sample Identification	Silver	Aluminum	Beryllium	Cadmium	Chromium	Copper	Iron	Mercury	Manganese	Nickel	Lead	Antimony	Zinc	Uranium
HVFSL-5	2.8	7680	1.1	<0.25	69.4	189	57800	<0.05	638	38	3.8	16.1	69	5.0
HVFFD-1	2.4	6620	0.91	<0.26	52.7	154	42900	<0.05	512	30	1.8	11.3	56.1	5.3
RPD	15.4	14.8	18.9	NA	27.4	20.4	29.6	NA	21.9	23.5	71.4	35.0	20.6	5.8
HVOSL-4	<0.41	3600	0.62	<0.26	14.4	41.9	24500	<0.051	266	11.1	1.8	7.4	36.1	<1.2
HVOFD-1	0.45	2690	0.59	<0.25	14.7	31.3	21200	<0.052	224	9.4	1.3	6.3	31.3	<1.4
RPD	NA	28.9	5.0	NA	2.1	29.0	14.4	NA	17.1	16.6	32.3	16.1	14.2	NA
HVCSL-3	1.3	3700	0.66	<0.26	8.7	118	22600	<0.051	280	14	3.3	8.2	44.2	4.8
HVCFD-1	1.5	4000	0.66	<0.27	9.1	123	23200	<0.051	293	15.6	4.5	7.5	46.9	5.6
RPD	14.3	7.8	0.0	NA	4.5	4.1	2.6	NA	4.5	10.8	30.8	8.9	5.9	15.4
HVDSL-2	18.9	25900	0.54	0.95	61.8	1020	35500	1.5	958	101	54.6	<5.7	127	51
HVDFD-1	17.3	21500	0.32	0.97	55	921	32400	1.7	833	89.4	49.4	<5.9	113	52
RPD	8.8	18.6	51.2	2.1	11.6	10.2	9.1	12.5	14.0	12.2	10.0	NA	11.7	1.9
HVRWA-1	68.4	58300	5.5	<2.6	205	6940	14600	10.2	4890	601	68	<25.4	401	540
HVRFD-1	39.1	72700	5.8	2.8	256	7360	27500	10.9	5330	633	130	31.1	438	480
RPD	54.5	22.0	5.3	NA	22.1	5.9	61.3	6.6	8.6	5.2	62.6	NA	8.8	11.8
HRFSL-4	1.1	3810	0.32	0.94	10.5	49.4	19900	<0.052	260	10.6	2.7	3.9	32.7	2.0
HRFFD-1	0.72	3080	0.23	0.54	6.9	41.5	16200	<0.052	244	9.6	2.6	<2.6	25.7	3.3
RPD	41.8	21.2	32.7	54.1	41.4	17.4	20.5	NA	6.3	9.9	3.8	NA	24.0	49.1
HROSL-3	0.63	2610	0.42	<0.26	13	26.2	16200	<0.051	186	10.7	0.83	7.9	26.7	<1.6
HROFD-1	0.55	1570	0.29	<0.25	6.1	34.2	9860	<0.051	118	6.3	3.1	4.7	16.7	1.8
RPD	13.6	49.8	36.6	NA	72.3	26.5	48.7	NA	44.7	51.8	115.5	50.8	46.1	NA
HRCSL-2	1.6	4620	0.74	<0.28	21	134	27000	<0.051	335	17.3	4	11.1	53.6	2.0
HRCFD-1	1.3	3180	0.65	<0.26	9.4	90.4	22800	<0.051	274	11.8	2.9	11.4	41.5	5.5
RPD	20.7	36.9	12.9	NA	76.3	38.9	16.9	NA	20.0	37.8	31.9	2.7	25.4	NA
HRDSL-1	14.9	20600	1.3	<0.73	50	788	31400	1.3	863	80.1	49.4	7.4	137	36
HRDFD-1	13.4	29400	1.8	<0.75	54.9	712	44000	0.81	1120	79.9	20.3	9.3	170	33
RPD	10.6	35.2	32.3	NA	9.3	10.1	33.4	46.4	25.9	0.2	83.5	22.8	21.5	8.7
HRRWA-5	<4.1	4100	0.3	<2.6	7.8	114	4010	<0.10	97	17	4	<25.4	131	120
HRRFD-1	<4.1	4780	0.5	<2.6	9.7	128	4470	<0.10	107	18.7	4.1	<25.4	77.5	130
RPD	NA	15.3	50.0	NA	21.7	11.6	10.8	NA	9.8	9.5	2.5	NA	51.3	8.0
HGAFFSL-3	21	13900	0.42	1.7	233	4050	27400	2.6	329	314	25.8	8.4	128	530
HGAFFD-1	16.8	12700	0.37	1.7	202	3760	19000	2.6	251	283	27.3	7.5	96.4	600
RPD	22.2	9.0	12.7	0.0	14.3	7.4	36.2	0.0	26.9	10.4	5.6	11.3	28.2	12.4
HGAOSL-2	5.6	3470	0.09	<0.29	30.7	365	18400	0.28	199	32.7	3.5	5.3	26.6	9.5
HGAOFD-1	4	3420	0.1	0.44	25.8	331	16100	0.4	193	30.8	4.2	<3.3	26.5	26
RPD	33.3	1.5	10.5	NA	17.3	9.8	13.3	35.3	3.1	6.0	18.2	NA	0.4	93.0
HGWCSL-1	6.2	5280	0.22	0.36	39	1140	18700	0.31	218	114	12.2	5.1	50.6	81
HGWCFD-1	6.3	6490	0.27	<0.29	50.5	1210	29900	0.32	324	122	9.8	7.8	63.8	75
RPD	1.6	20.6	20.4	NA	25.7	6.0	46.1	3.2	39.1	6.8	21.8	41.9	23.1	7.7
HGADSL-5	128	63400	<0.079	7.5	1230	22100	11400	19.3	346	1560	172	28.4	389	2520
HGADFD-1	110	63900	0.11	7.5	1240	22200	11900	17.3	354	1560	160	28.8	390	1890
RPD	15.1	0.8	NA	0.0	0.8	0.5	4.3	10.9	2.3	0.0	7.2	1.4	0.3	28.6
HGARWA-4	8.3	6940	0.5	<2.6	121	2550	674	0.59	37.6	189	6.6	<25.4	70.5	2500
HGARFD-1	9.4	6920	0.5	<2.6	120	2540	756	0.47	37.6	184	21.6	<25.4	77.5	3000
RPD	12.4	0.3	0.0	NA	0.8	0.4	11.5	22.6	0.0	2.7	106.4	NA	9.5	18.2

Table 4-2. Comparison of the Laboratory Results for Process Samples and Field Duplicate Samples Analyzed by Roy F. Weston/Teledyne. (sheet 2 of 2)

Sample Identification	Uranium-235	Uranium-238	Cobalt-60	Cesium-137	Thorium-228	Potassium-40
HVFSL-5		1.7				
HVFFD-1		1.8				
RPD		5.7				
HVOSL-4		<0.4				
HVOFD-1		<0.5				
RPD		NA				
HVCSL-3		1.6				
HVCFD-1		1.9				
RPD		15.4				
HVDSL-2		17				
HVDFD-1		12				
RPD		34.5				
HVRWA-1	9.6	180	6.95	6.45	13.4	153
HVRFD-1	7.8	160	8.11	6.57	16.3	127
RPD	20.7	11.8	15.4	1.8	19.5	18.6
HRFSL-4		0.7				
HRFFD-1		1.1				
RPD		44.4				
HROSL-3		<0.5				
HROFD-1		0.6				
RPD		NA				
HRCSL-2		<0.7				
HRCFD-1		1.8				
RPD		NA				
HRDSL-1	0.56	12	0.917	0.349	1.5	20.2
HRDFD-1	0.58	11	0.698	0.229	1.21	16.6
RPD	3.5	8.7	27.1	41.5	21.4	19.6
HRRWA-5		40				
HRRFD-1		43				
RPD		7.2				
HGAFL-3		177				
HGAFFD-1		200				
RPD		12.2				
HGAOSL-2		3.2				
HGAOFD-1		8.7				
RPD		92.4				
HGWCSL-1	1.3	27	<0.05	0.291	2.57	9.53
HGWCFD-1	1.2	25	<0.05	0.28	2.75	10.6
RPD	8.0	7.7	NA	3.9	6.8	10.6
HGADSL-5	54	840	1.07	0.819	23.9	10.1
HGADFD-1	38	630	0.909	0.607	23	8.76
RPD	34.8	28.6	16.3	29.7	3.8	14.2
HGARWA-4		833				
HGARFD-1		1000				
RPD		18.2				

Table 4-3. Comparison of the Laboratory Results for Process Samples Analyzed by Roy F. Weston/Teledyne and Field Split Samples Analyzed by Data Chem Laboratories.
(sheet 1 of 2)

Sample Identification	Silver	Aluminum	Beryllium	Cadmium	Chromium	Copper	Iron	Mercury	Manganese	Nickel	Lead	Antimony	Zinc	Uranium
HVFSL-5	2.8	7680	1.1	<0.25	69.4	189	57800	<0.05	638	38	3.8	16.1	69	5
HVFSL-10 (Split)	0.55	7520	0.32	<0.31	50.5	139	41100	<0.1	500	29.2	4.0	<5.2	61.2	5.85
RPD	134.3	2.1	109.9	NA	31.5	30.5	33.8	NA	24.3	26.2	5.1	NA	12.0	15.7
HVOSL-4	<0.41	3600	0.62	<0.26	14.4	41.9	24500	<0.051	266	11.1	1.8	7.4	36.1	<0.6
HVOSL-10 (Split)	<0.41	4820	0.16	<0.31	12.5	33.2	26700	<0.10	319	11.3	4.3	<5.1	47.8	2.3
RPD	NA	29.0	117.9	NA	14.1	23.2	8.6	NA	18.1	1.8	82.0	NA	27.9	NA
HVCSL-3	1.3	3700	0.66	<0.26	8.7	118	22600	<0.051	280	14	3.3	8.2	44.2	4.8
HVCSL-10 (Split)	<0.41	6080	0.28	<0.31	12.8	121	35400	<0.1	402	16.5	4.2	5.6	68.1	4.6
RPD	NA	48.7	80.9	NA	38.1	2.5	44.1	NA	35.8	16.4	24.0	37.7	42.6	4.3
HVDSL-2	18.9	25900	0.54	0.95	61.8	1020	35500	1.5	958	101	54.6	<5.7	127	51
HVDSL-10 (Split)	15.3	31800	1.3	<0.69	69.8	1040	38500	1.2	972	106	44.5	<11.4	140	38.1
RPD	21.1	20.5	82.6	NA	12.2	1.9	8.1	22.2	1.5	6.8	20.4	NA	9.7	29.0
HVRWA-1	68.4	58300	5.5	<2.6	205	6940	14600	10.2	4890	601	68	<25.4	401	540
HVRWA-10 (Split)	151	288000	12.7	3.2	614	9540	319000	12.4	2790	946	23	<26	1110	253
RPD	75.3	132.7	79.1	NA	99.9	31.6	182.5	19.5	54.7	44.6	98.9	NA	93.8	72.4
HRFSL-4	1.1	3810	0.32	0.94	10.5	49.4	19900	<0.052	260	10.6	2.7	3.9	32.7	2.0
HRFSL-11 (Split)	0.74	9230	0.36	<0.31	14.6	110	30900	0.1	431	16.8	12.2	<5.2	59.9	9.0
RPD	39.1	83.1	11.8	NA	32.7	76.0	43.3	NA	49.5	45.3	127.5	NA	58.7	127.1
HROS-3	0.63	2610	0.42	<0.26	13	26.2	16200	<0.051	186	10.7	0.83	7.9	26.7	<0.8
HROS-11 (Split)	<0.41	5650	0.26	<0.31	17.9	34.4	28100	<0.10	319	16.9	4.2	<5.1	48.2	2.4
RPD	NA	73.6	47.1	NA	31.7	27.1	53.7	NA	52.7	44.9	134.0	NA	57.4	NA
HRCSL-2	1.6	4620	0.74	<0.28	21	134	27000	<0.051	335	17.3	4	11.1	53.6	<2.0
HRCSL-11 (Split)	<0.41	5620	<0.31	<0.31	10.8	91.8	34400	<0.1	395	13.7	4.1	<5.1	66.1	4.3
RPD	NA	19.5	NA	NA	64.2	37.4	24.1	NA	16.4	23.2	2.5	NA	20.9	NA
HRDSL-1	14.9	20600	1.3	<0.73	50	788	31400	1.3	863	80.1	49.4	7.4	137	36
HRDSL-11 (Split)	14.5	34300	1.3	<0.83	66.7	929	41300	0.99	1050	99.9	51.4	<13.9	175	41
RPD	2.7	49.9	0.0	NA	28.6	16.4	27.2	27.1	19.6	22.0	4.0	NA	24.4	12.5
HRRWA-5	<4.1	4100	0.3	<2.6	7.8	114	4010	<0.10	97	17	4	<25.4	131	120
HRRWA-11 (Split)	<3.4	4570	<1.5	<3.0	<20.0	136	4560	<0.10	115	<16	2.7	<26	20	110
RPD	NA	10.8	NA	NA	NA	17.6	12.8	NA	17.0	NA	38.8	NA	147.0	8.7
HGAFL-3	21	13900	0.42	1.7	233	4050	27100	2.6	329	314	25.8	8.4	128	530
HGAFL-6	36.7	15300	0.48	0.49	207	3450	35300	2.4	418	278	22.1	<5.2	106	488
RPD	54.4	9.6	13.3	110.5	11.8	16.0	26.3	8.0	23.8	12.2	15.4	NA	18.8	8.3
HGAOSL-2	5.6	3470	0.09	<0.29	30.7	365	18400	0.29	199	32.7	3.5	5.3	26.6	9.5
HGAOSL-6 (Split)	4.3	7360	0.21	<0.30	38.9	432	28000	0.29	352	42.9	4	<5.0	50.7	88.7
RPD	26.3	71.8	80.0	NA	23.6	16.8	41.4	0.0	55.5	27.0	13.3	NA	62.4	161.3
HGWCSL-1	6.2	5280	0.22	0.36	39	1140	18700	0.31	218	114	12.2	5.1	50.6	81
HGWCSL-5 (Split)	5.6	8540	0.33	0.35	55.4	1210	38600	0.34	500	125	10	<5.1	90	81.3
RPD	10.2	47.2	40.0	NA	34.7	6.0	69.5	9.2	78.6	9.2	19.8	NA	56.0	0.4
HGADSL-5	128	63400	<0.079	7.5	1230	22100	11400	19.3	346	1560	172	28.4	389	2520
HGADSL-6 (Split)	294	69800	2.3	3.2	1340	23600	15000	16.9	387	1700	153	<19.5	393	3580
RPD	78.7	9.6	NA	80.4	8.6	6.6	27.3	13.3	11.2	8.6	11.7	NA	1.0	34.8
HGARWA-4	8.3	6940	0.5	<2.6	121	2550	674	0.59	37.6	189	6.6	<25.4	70.5	2500
HGARWA-8 (Split)	19.2	8270	<1.5	<3.0	155	3050	897	1.2	45.8	238	17	<26	55.5	2780
RPD	79.3	17.5	NA	NA	24.6	17.9	28.4	68.2	19.7	23.0	88.1	NA	23.8	10.6

Table 4-3. Comparison of the Laboratory Results for Process Samples Analyzed by Roy F. Weston/Teledyne and Field Split Samples Analyzed by Data Chem Laboratories.
(sheet 2 of 2)

Sample Identification	Uranium-235	Uranium-238	Cobalt-60	Cesium-137	Thorium-228	Potassium-40
HVFSL-5		1.7				
HVFSL-10 (Split)		1.95				
RPD		15.7				
HVOSL-4		<0.2				
HVOSL-10 (Split)		0.8				
RPD		NA				
HVCSL-3		1.6				
HVCSL-10 (Split)		1.5				
RPD		4.3				
HVDSL-2		17				
HVDSL-10 (Split)		13				
RPD		29.0				
HVRWA-1	9.6	180	6.95	6.45	13.4	153
HVRWA-10 (Split)	11.7	84.3	<10.4	<7.4	<27.7*	<170
RPD	19.7	72.4	NA	NA	NA	NA
HRFSL-4		0.7				
HRFSL-11 (Split)		3.0				
RPD		127.1				
HROSL-3		<0.3				
HROSL-11 (Split)		0.8				
RPD		NA				
HRCSL-2		<0.7				
HRCSL-11 (Split)		1.4				
RPD		NA				
HRDSL-1	0.56	12	0.917	0.349	1.5	20.2
HRDSL-11 (Split)	0.708	13.6	0.634	0.482	<1.04*	15
RPD	23.3	12.5	36.5	32.0	NA	29.5
HRRWA-5		40				
HRRWA-11 (Split)		37				
RPD		8.6				
HGAFL-3		177				
HGAFL-6 (Split)		163				
RPD		8.4				
HGAOSL-2		3.2				
HGAOSL-6 (Split)		30				
RPD		160.9				
HGWCSL-1	1.3	27	<0.05	0.291	2.57	9.53
HGWCSL-5 (Split)	1.49	27.1	<0.05	0.318	3.06*	8.35
RPD	13.6	0.4	NA	8.9	17.4	13.2
HGADSL-5	54	840	1.07	0.819	23.9	10.1
HGADSL-6 (Split)	93.3	1193	0.926	1.03	20.1*	6.56
RPD	53.4	34.8	14.4	22.8	17.3	42.5
HGARWA-4		833				
HGARWA-8 (Split)		927				
RPD		10.6				

* Thorium-228 values are converted from Thorium-232 results provided by Datachem assuming secular equilibrium.

Table 4-4. Summary of Field XRF Analyses and Comparison to Laboratory Analyses. (sheet 1 of 6)

Sample ID	Copper Concentration (mg/kg)				Uranium Concentration (mg/kg)			
	XRF	R.F. Weston	RPD	Difference	XRF	Teledyne	RPD	Difference
PREPROCESSING SAMPLING								
HPGSL-004	583	508	14	75	26	20	26	6
HPGSL-005	<75	NA	NA	NA	<25	4.4	NA	NA
HPGSL-006	<75	NA	NA	NA	<25	1.7	NA	NA
HPGSL-007	<75	NA	NA	NA	<25	2.5	NA	NA
HPFSL-V	137	127	8	10	<25	3.8	NA	NA
HPFSL-R	90	61.6	37	28	<25	3	NA	NA
HPFSL-G	4173	2260	59	1913	405	340	17	65
VERIFICATION RUN								
FEED SOIL								
HVFSL-001	90	102	13	12	<25	2.4	NA	NA
HVFSL-002	147	165	12	18	<25	4.2	NA	NA
HVFSL-003	128	128	0	0	<25	4.5	NA	NA
HVFSL-004	149	161	8	12	<25	5	NA	NA
HVFSL-005	104	189	58	85	<25	5	NA	NA
HVFSL-006	230	202	13	28	<25	4.8	NA	NA
HVFSL-007	106	113	6	7	<25	4.4	NA	NA
HVFSL-008	134	138	3	4	<25	6.6	NA	NA
HVFSL-009	<75	108	NA	NA	<25	2.2	NA	NA
PROCESS OVERSIZE								
HVOSL-001	<75	62.6	NA	NA	<25	0.6	NA	NA
HVOSL-002	<75	33.9	NA	NA	<25	2	NA	NA
HVOSL-003	<75	29.6	NA	NA	<25	<0.8	NA	NA
HVOSL-004	<75	41.9	NA	NA	<25	<0.6	NA	NA
HVOSL-005	<75	26.4	NA	NA	<25	<1.0	NA	NA
HVOSL-006	<75	32.1	NA	NA	<25	2.4	NA	NA
HVOSL-007	<75	36.2	NA	NA	<25	<0.7	NA	NA
HVOSL-008	76	36.0	71	40	<25	<0.8	NA	NA
HVOSL-009	<75	31.3	NA	NA	<25	2.7	NA	NA
CLEAN SAND								
HVCSL-001	136	120	13	16	<25	3.9	NA	NA
HVCSL-002	195	117	50	78	<25	5.9	NA	NA
HVCSL-003	171	118	37	53	<25	4.8	NA	NA
HVCSL-004	132	150	13	18	<25	4.6	NA	NA
HVCSL-005	122	103	17	19	<25	4.1	NA	NA
HVCSL-006	204	131	44	73	<25	5.2	NA	NA
HVCSL-007	146	111	27	35	<25	3.4	NA	NA
HVCSL-008	162	93.5	54	69	<25	4	NA	NA
HVCSL-009	147	107	31	40	<25	3.4	NA	NA

Table 4-4. Summary of Field XRF Analyses and Comparison to Laboratory Analyses. (sheet 2 of 6)

Sample ID	XRF	Copper Concentration (mg/kg)			XRF	Uranium Concentration (mg/kg)		
		R.F. Weston	RPD	Difference		Teledyne	RPD	Difference
FINES								
HVDSL-001	996	1070	7	74	52	36	36	16
HVDSL-002	1038	1020	2	18	51	51	0	0
HVDSL-003	1001	941	6	60	54	53	2	1
HVDSL-004	1005	857	16	148	50	70	33	20
HVDSL-005	1063	954	11	109	47	55	16	8
HVDSL-006	1032	1130	9	98	51	58	13	7
HVDSL-007	992	924	7	68	55	71	25	16
HVDSL-008	946	988	4	42	52	66	24	14
HVDSL-009	891	866	3	25	53	33	47	20
REPLICATION RUN								
FEED SOIL								
HRFSL-001	138	130	6	8	<25	3.6	NA	NA
HRFSL-002	174	143	20	31	<25	3.2	NA	NA
HRFSL-003	133	106	23	27	<25	5.2	NA	NA
HRFSL-004	<75	49.4	NA	NA	<25	2	NA	NA
HRFSL-005	94	49.6	62	44	<25	3.9	NA	NA
HRFSL-006	<75	53.5	NA	NA	<25	2.3	NA	NA
HRFSL-007	98	83.3	16	15	<25	4	NA	NA
HRFSL-008	94	69.2	30	25	<25	4.8	NA	NA
HRFSL-009	88	57.2	42	31	<25	4.7	NA	NA
HRFSL-010	122	51.9	81	70	<25	2.2	NA	NA
PROCESS OVERSIZE								
HROSL-001	<75	17	NA	NA	<25	0.7	NA	NA
HROSL-002	<75	25.3	NA	NA	<25	2.4	NA	NA
HROSL-003	<75	26.2	NA	NA	<25	<0.8	NA	NA
HROSL-004	<75	17.7	NA	NA	<25	<0.7	NA	NA
HROSL-005	<75	29.1	NA	NA	<25	2.2	NA	NA
HROSL-006	<75	35.8	NA	NA	<25	1.6	NA	NA
HROSL-007	<75	26.1	NA	NA	<25	2.8	NA	NA
HROSL-008	<75	23.2	NA	NA	<25	<0.7	NA	NA
HROSL-009	<75	23.5	NA	NA	<25	2.5	NA	NA
HROSL-010	<75	24.2	NA	NA	<25	0.5	NA	NA
CLEAN SAND								
HRCSL-001	115	97.1	17	18	<25	3.3	NA	NA
HRCSL-002	131	134	2	3	<25	2	NA	NA
HRCSL-003	129	88.1	38	41	<25	6.7	NA	NA
HRCSL-004	133	110	19	23	<25	4.5	NA	NA
HRCSL-005	151	85.9	55	65	<25	3.6	NA	NA
HRCSL-006	101	91.8	10	9	<25	4.3	NA	NA
HRCSL-007	<75	84.8	NA	NA	<25	4.6	NA	NA
HRCSL-008	97	90.2	7	7	<25	4.8	NA	NA
HRCSL-009	141	98.2	36	43	<25	4.8	NA	NA
HRCSL-010	120	92.4	26	28	<25	3.3	NA	NA

Table 4-4. Summary of Field XRF Analyses and Comparison to Laboratory Analyses. (sheet 3 of 6)

Sample ID	XRF	Copper Concentration (mg/kg)			XRF	Uranium Concentration (mg/kg)		
		R.F. Weston	RPD	Difference		Teledyne	RPD	Difference
FINES								
HRDSL-001	971	788	21	183	51	36	34	15
HRDSL-002	893	870	3	23	49	50	2	1
HRDSL-003	828	877	6	49	38	50	27	12
HRDSL-004	769	774	1	5	46	42	9	4
HRDSL-005	758	732	3	26	52	47	10	5
HRDSL-006	570	527	8	43	48	53	10	5
HRDSL-007	612	573	7	39	34	44	26	10
HRDSL-008	602	579	4	23	41	45	9	4
HRDSL-009	587	736	23	149	40	48	18	8
HRDSL-010	568	681	18	113	42	26	47	16
URANIUM CARBONATE RUN								
FEED SOIL								
HGAFSL-1	2375	1680	34	695	233	270	15	37
HGAFSL-2	4596	3480	28	1116	456	560	20	104
HGAFSL-3	4384	4050	8	334	435	530	20	95
HGAFSL-4	3974	3060	26	914	449	380	17	69
HGAFSL-5	2661	1570	52	1091	253	243	4	10
PROCESS OVERSIZE								
HGAOSL-1	269	217	21	52	37	26	35	11
HGAOSL-2	320	365	13	45	41	9.5	125	32
HGAOSL-3	187	161	15	26	<25	20	NA	NA
HGAOSL-4	166	155	7	11	30	19	45	11
HGAOSL-5	88	98.7	11	11	<25	8.1	NA	NA
CLEAN SAND								
HGWCSL-1	1199	1140	5	59	71	81	13	10
HGWCSL-2	1637	1400	16	237	114	99	14	15
HGWCSL-3	1074	1050	2	24	65	83	24	18
HGWCSL-4	1024	1130	10	106	66	78	17	12
FINES								
HGADSL-1	20445	16800	20	3645	2460	2970	19	510
HGADSL-2	28376	22300	24	6076	3357	6600	65	3243
HGADSL-3	29763	25200	17	4563	3500	6400	59	2900
HGADSL-4	30399	23400	26	6999	3518	6400	58	2882
HGADSL-5	31050	22100	34	8950	3597	2520	35	1077
HGWDSL-1	26582	22700	16	3882	3127	4800	42	1673

Table 4-4. Summary of Field XRF Analyses and Comparison to Laboratory Analyses. (sheet 4 of 6)

Sample ID	XRF	Copper Concentration (mg/kg)			XRF	Uranium Concentration (mg/kg)		
		R.F. Weston	RPD	Difference		Teledyne	RPD	Difference
VERIFICATION RUN								
FEED SOIL								
HVF1SL-FRCA	<75	74.4	NA	NA	<25	1.9	NA	NA
HVF1SL-FRCB	<75	52.6	NA	NA	<25	<0.7	NA	NA
HVF1SL-FRCC	<75	89	NA	NA	<25	1.8	NA	NA
HVF1SL-FRCD	<75	47	NA	NA	<25	2.2	NA	NA
HVF1SL-FRCE	107	97.6	9	9	<25	2.9	NA	NA
HVF1SL-FRCF	125	115	8	10	<25	2.7	NA	NA
HVF1SL-FRCG	192	139	32	53	<25	5.3	NA	NA
HVF1SL-FRCH	262	193	30	69	<25	14	NA	NA
HVF1SL-FRCI	483	297	48	186	<25	17	NA	NA
HVF1SL-FRCJ	555	449	21	106	<25	25	NA	NA
HVF1SL-FRCK	957	940	2	17	53	68	25	15
HVF2SL-FRCA	<75	46.6	NA	NA	<25	2	NA	NA
HVF2SL-FRCB	<75	46.2	NA	NA	<25	1.9	NA	NA
HVF2SL-FRCC	<75	54.4	NA	NA	<25	2.6	NA	NA
HVF2SL-FRCD	94	50.7	60	43	<25	2.1	NA	NA
HVF2SL-FRCE	<75	69.8	NA	NA	<25	2.1	NA	NA
HVF2SL-FRCF	140	96	37	44	<25	4.6	NA	NA
HVF2SL-FRCG	183	116	45	67	<25	6.8	NA	NA
HVF2SL-FRCH	237	155	42	82	<25	13	NA	NA
HVF2SL-FRCK	750	760	1	10	44	49	11	5
PROCESS OVERSIZE								
HVO1SL-FRCA	<75	31.2	NA	NA	<25	<0.7	NA	NA
HVO1SL-FRCB	<75	35.7	NA	NA	<25	1.9	NA	NA
HVO1SL-FRCC	<75	34.4	NA	NA	<25	<0.9	NA	NA
HVO1SL-FRCD	<75	49.6	NA	NA	<25	2.9	NA	NA
HVO1SL-FRCE	<75	62.7	NA	NA	<25	3.2	NA	NA
HVO1SL-FRCF	212	139	42	73	<25	<4.0	NA	NA
HVO2SL-FRCA	<75	60.4	NA	NA	<25	2	NA	NA
HVO2SL-FRCB	<75	33	NA	NA	<25	2.6	NA	NA
HVO2SL-FRCC	<75	50.3	NA	NA	<25	1.8	NA	NA
HVO2SL-FRCD	<75	44.4	NA	NA	<25	3.4	NA	NA
HVO2SL-FRCE	<75	74.9	NA	NA	<25	<0.9	NA	NA
CLEAN SAND								
HVC1SL-FRCF	144	107	29	37	<25	3.8	NA	NA
HVC1SL-FRCG	158	109	37	49	<25	4.2	NA	NA
HVC1SL-FRCH	283	168	51	115	<25	12	NA	NA
HVC1SL-FRCI	396	294	30	102	<25	11	NA	NA
HVC1SL-FRCJ	340	346	2	6	<25	12	NA	NA
HVC1SL-FRCK	1429	1460	2	31	<25	62	NA	NA
HVC2SL-FRCF	138	119	15	19	<25	4	NA	NA
HVC2SL-FRCG	163	130	23	33	<25	7.5	NA	NA
HVC2SL-FRCH	251	158	45	93	<25	4.2	NA	NA
HVC2SL-FRCI	227	242	6	15	<25	8.2	NA	NA
HVC2SL-FRCK	1019	1170	14	151	47	73	43	26

Table 4-4. Summary of Field XRF Analyses and Comparison to Laboratory Analyses. (sheet 5 of 6)

Sample ID	XRF	Copper Concentration (mg/kg)			Uranium Concentration (mg/kg)			
		R.F. Weston	RPD	Difference	XRF	Teledyne	RPD	Difference
REPLICATION RUN								
FEED SOIL								
HRF1SL-FRCA	<75	34.3	NA	NA	<25	1.3	NA	NA
HRF1SL-FRCB	<75	37.5	NA	NA	<25	2.4	NA	NA
HRF1SL-FRCC	<75	36.1	NA	NA	<25	2.9	NA	NA
HRF1SL-FRCD	<75	47.5	NA	NA	<25	1.9	NA	NA
HRF1SL-FRCE	76	74.6	2	1	<25	5.1	NA	NA
HRF1SL-FRCF	114	87.5	26	27	<25	3.6	NA	NA
HRF1SL-FRCG	177	141	23	36	<25	5.2	NA	NA
HRF1SL-FRCH	171	145	16	26	<25	10	NA	NA
HRF1SL-FRCI	377	256	38	121	<25	15	NA	NA
HRF1SL-FRCJ	450	355	24	95	<25	26	NA	NA
HRF1SL-FRCK	694	726	5	32	44	45	2	1
HRF2SL-FRCA	NS	NS	NA	NA	<25	NS	NA	NA
HRF2SL-FRCB	<75	45.6	NA	NA	<25	3.5	NA	NA
HRF2SL-FRCC	<75	60.4	NA	NA	<25	1.6	NA	NA
HRF2SL-FRCD	<75	48.2	NA	NA	<25	1.7	NA	NA
HRF2SL-FRCE	79	64.5	20	15	<25	2.4	NA	NA
HRF2SL-FRCF	143	100	35	43	<25	3.5	NA	NA
HRF2SL-FRCG	126	114	10	12	<25	5.6	NA	NA
HRF2SL-FRCH	202	149	30	53	<25	14	NA	NA
HRF2SL-FRCK	606	696	14	90	27	44	48	17
PROCESS OVERSIZE								
HRO1SL-FRCA	<75	46.1	NA	NA	<25	2.7	NA	NA
HRO1SL-FRCB	<75	37.1	NA	NA	<25	4	NA	NA
HRO1SL-FRCC	<75	39.5	NA	NA	<25	1.8	NA	NA
HRO1SL-FRCD	<75	55.6	NA	NA	<25	4.7	NA	NA
HRO1SL-FRCE	<75	56	NA	NA	<25	2.8	NA	NA
HRO1SL-FRCF	<75	206	NA	NA	<25	6.3	NA	NA
HRO2SL-FRCA	<75	36.6	NA	NA	<25	3.2	NA	NA
HRO2SL-FRCB	<75	32.9	NA	NA	<25	2.2	NA	NA
HRO2SL-FRCC	<75	36.3	NA	NA	<25	<0.9	NA	NA
HRO2SL-FRCD	<75	64.1	NA	NA	<25	2.6	NA	NA
HRO2SL-FRCE	<75	60.6	NA	NA	<25	2.9	NA	NA
CLEAN SAND								
HRC1SL-FRCF	100	88.6	12	11	<25	<1.0	NA	NA
HRC1SL-FRCG	137	101	30	36	<25	6.6	NA	NA
HRC1SL-FRCH	162	143	12	19	<25	12	NA	NA
HRC1SL-FRCI	252	196	25	56	<25	20	NA	NA
HRC1SL-FRCJ	745	929	22	184	41	59	36	18
HRC2SL-FRCF	103	93.7	9	9	<25	3.6	NA	NA
HRC2SL-FRCG	113	105	7	8	<25	5.4	NA	NA
HRC2SL-FRCH	206	124	50	82	<25	5.9	NA	NA
HRC2SL-FRCI	232	160	37	72	<25	19	NA	NA

Table 4-4. Summary of Field XRF Analyses and Comparison to Laboratory Analyses. (sheet 6 of 6)

Sample ID	XRF	Copper Concentration (mg/kg)			XRF	Uranium Concentration (mg/kg)		
		R.F. Weston	RPD	Difference		Teledyne	RPD	Difference
GREEN RUN								
OVERSIZE								
HGAO1SL-FRCA	<75	65.4	NA	NA	<25	1.9	NA	NA
HGAO1SL-FRCB	<75	67.5	NA	NA	<25	2.9	NA	NA
HGAO1SL-FRCC	76	68.9	10	7	<25	4.4	NA	NA
HGAO1SL-FRCD	360	223	47	137	37	25	39	12
HGAO1SL-FRCE	565	368	42	197	56	54	4	2
HGAO1SL-FRCF	2804	3370	18	566	394	860	74	466
HGAO1SL-FRCG	28925	23800	19	5125	3349	6900	69	3551
HGAO2SL-FRCA	<75	54.8	NA	NA	<25	3.8	NA	NA
HGAO2SL-FRCB	<75	60.7	NA	NA	<25	3.9	NA	NA
HGAO2SL-FRCC	79	62.8	23	16	<25	5.3	NA	NA
HGAO2SL-FRCD	158	124	24	34	<25	11	NA	NA
HGAO2SL-FRCE	1116	1110	1	6	157	230	38	73
Average RPD			22		29			

5.0 CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations that were derived from the data and operational experience gained during completion of the study can be divided into three general areas: the physical/chemical characteristics of the soils at the site; the performance of the physical separation technology with respect to the project objectives; and operational issues associated with full scale implementation of soil washing as a remedy. Each of the three general areas are discussed below.

5.1 PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE SITE SOILS

The North Process Pond contains soils having a general particle size distribution of approximately 75% oversize, 20% sand, and 5% fines on a dry-weight basis. Specifically, the feed to a physical separation plant treating the "green material" will result in, on a dry-weight basis, 68% oversize (> 4 mm), 28% sand (> 0.075 mm and < 4 mm), and 4% fines (< 0.075 mm). The particle size distribution and in particular the low contribution of fine sands (0.045 mm to 0.250 mm) makes the soils ideal for physical separation.

The only constituent that was present in the feed soils at a concentration above the test performance criteria was uranium-238. This constituent appears to be strongly associated with the uranium carbonate material identified along the western side of the North Process Pond. Given the relative ratios between uranium-238, the other contaminants and the test performance criteria, and assuming that the relative ratios of the test performance criteria do not change during development of the remediation goals, performance of the remedy selected will be governed by its efficiency in treating uranium-238.

For the feed soil, the variation in the concentration of uranium-238 and the other constituents that appeared to be associated with the wastes managed at the site spanned two orders of magnitude or more. This wide variation, in combination with the development of the preliminary remediation goals, indicates that a large mass of soil at the site may or may not require remediation.

5.2 STUDY PERFORMANCE WITH RESPECT TO PROJECT OBJECTIVES

The principal objective of the study was to determine if the physical separation approach would be effective in attaining a 90% volume reduction while meeting the defined test performance criteria. For the soils that did not contain visible concentrations of "green" material, a volume reduction of 93.8% was achieved, while in the processing of the soils containing the green uranium carbonate materials, a 91.4% volume reduction was obtained. For both source materials, the clean products (the oversize and the sand) had constituent concentrations that were significantly less than the test performance criteria.

All process oversize streams and the clean sand streams from the verification and replication runs met the test performance criteria without additional treatment. The sand fraction from the uranium carbonate run required attritioning to meet the test performance criteria.

Although the process oversize stream from the uranium carbonate run met the test performance criteria, visual observations and field GM readings indicated that, with process changes in the feed rate, overloading of the screen could be minimized and improved product quality would result.

To minimize the total solids carried through the recycled water system, it was necessary when processing soils that had no "green" material to add a cationic polymer to the water treatment system in addition to the anionic flocculent. The addition of the cationic polymer reduced the mass of suspended solids, and consequently the contaminant load, by a factor approaching 100. The use of the cationic polymer was not required when processing the "green" material.

Decontamination of the pilot plant was an integral and significant component of the work effort. The successful decontamination and release of the majority of the plant components to ART indicated that the radionuclides contained in the North Process Pond soils can be removed from the treatment plant surfaces without sacrificing the structural integrity of the majority of the components.

5.3 OPERATIONAL CONSIDERATIONS FOR FULL-SCALE IMPLEMENTATION

In the event that physical separations/soil washing is selected as the site remedy, several operations considerations can be established based on the data and experience gained during this pilot study.

Due to the large mass of gross oversize, transport of the excavated soils to a central staging area for prescreening followed by transportation of the gross oversize back to the excavated area would involve substantial material handling and cost. If the remediation goal is set at a level to allow dry screening of the excavated soil, prescreening in the immediate vicinity of the excavation appears appropriate. Further, field observations qualitatively support an increase in the prescreen size to 75 mm to maximize the load of oversize surficially contaminated with green material and thereby optimize the removal of contamination from the 50-mm to 75-mm fraction.

The large uncertainty associated with the volume of soil to be processed (DOE-RL 1994b) has a major impact on the size and complexity of a physical separation plant sufficient to treat the soils designated for remediation.

To minimize overloading of the wet screen and maximize the treatment of the uranium carbonate sludge, it may be beneficial to increase the screen slot size up to 4 mm to maximize the amount of "green" material entering the hydrocyclone and the attrition scrubber.

If the remediation goal established for uranium-238 is near or below the test performance criteria, attritioning will be required to meet the remediation goal for the sand fraction using a water-only physical separation process. Because it is necessary to create an aqueous slurry to feed attritioning mills and scrubbers, it is appropriate use of hydrocyclone technology to separate and manage the attritioned product. By optimizing the separation, the use of hydrocyclones will have the added benefit of reducing the amount of concentrate that will be disposed at the ERDF when compared to simply screening approaches.

A hydrocyclone system capable of making a particle size separation in the range of 0.075 mm is recommended based on the soil types found at the site.

In lieu of a determination that the soils in the North Process Pond contain a listed hazardous waste, the residues from the treated of the site soils do not exhibit a RCRA characteristic and are not a hazardous waste. The ability to handle the feed soil and process products without the constraints associated with RCRA hazardous waste treatment will greatly simplify onsite products management.

During material excavation and processing, onsite field analyses using XRF technology to monitor for uranium is recommended. The study has demonstrated good sensitivity and reliability of the instrumentation at low activities (8 pCi/g) of uranium. Further, in several areas within the operable unit, uranium-238 is the key constituent governing the site risk (DOE-RL 1994b).

A full-scale system is likely to improve on the performance of the pilot plant used in this study based on several factors. First, in a full-scale system, hydrocyclones connected in series are typically used to sharpen the separation between the sand and fines fraction. The efficiencies of the hydrocyclones are somewhat additive such that two cyclones of 90% efficiency will have a combined efficiency in series approaching 99%. Also, to optimize the full scale system, the plant should include an attritioning system that will address both the process oversize as well as increase both the residence time and pulp density in the attrition scrubber used to treat the sand.

The performance objectives were clearly achieved.

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